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ROUGH DRAFT

OF

A MANUAL

OF

INDIAN SYLVICULTURE

BY

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PART I.

GENERAL PRINCIPLES.

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PREFACE.

This book is no more than what it professes to be, *viz.*, a Rough Draft of a Manual embodying especially for the use of Indian students the general principles of sylviculture.

It originated in this wise. In 1881, when instruction was given for the first time at the Forest School, Mr. Fisher and I were asked to prepare a Manual of Forestry to take the place of the lectures. The task of bringing out the Sylviculture portion of the book fell to me. As the undertaking was a very large one and required more experience than a single man possessed, Mr. R. Thompson joined us in 1882, and I was relieved of that portion of the work, which relates to the special application of general principles in the cultivation and treatment of our forests and trees. Thus my allotted task has now been completed.

In carrying it out I have never had the time or the opportunity to complete the entire book in manuscript before publishing it. As each section, indeed often each Article, was written, it was sent to press, and so when the later parts came to be written in the same piece-meal fashion, I constantly felt the necessity of suppressing, modifying or adding to was already in print. Nay more than this. Owing to special duties which absorbed all my time, I have frequently for months been compelled to lay the work aside until I had once more leisure to resume it. Indeed on one occasion not a word was was added to the manuscript for more than a year. Even when able to prosecute the work, I could make for myself time only at nights in the solitude of our forest camps. Such being the case, it is not surprising that the first page was printed in November 1885, while the last one is only just leaving the press after a lapse of three years. During this time I have also been preparing in Urdu a course of forestry and the allied sciences for the use of candidates for the Forester's certificate, part of which course has already been published. It will thus be readily conceded that the circumstances in which this Draft has been written and published have been conducive neither to unity of ideas, plan or arrangement, nor even to the little amount of literary polish that is generally held to be sufficient in an educational work on a scientific subject.

When I adopted the plan of publication just described, I was of course aware of the enormous disadvantages under which I would

have to labour. But I had to consider before everything the interests of our students, who have quite enough to do without having to write out voluminous notes, which, always much less readable than the worst description of type, very few of them are sufficiently well educated to take down accurately. Hence as form after form of the draft was received from the press, it was put into the hands of the men with very great advantage both to the teacher and the taught. Even if the entire book was not available, still the proverbial half loaf was better than none at all. I have Mr. Smythies' permission to say that when last year he took my place at the School, he found his work very much facilitated by the 438 pages that were then in print.

I must now say a few words regarding the plan and scope of the work.

In the present inchoate condition of Indian forestry, the very imperfect knowledge we possess of the habits and requirements of our species in their various surroundings, and the impossibilty or impracticability of applying any advanced system of culture in the regeneration and treatment of all but an infinitesimal portion of our forests, systems of regeneration and treatment have for us much less importance than the accurate observation of natural phenomena and correct deduction of principles therefrom. For this reason I have laid particular stress on the struggle for existence that is constantly going on between the component individuals of a forest crop, and have made a special study of the conditions which decide the survival of the fittest. This, it seems to me, is an entirely new departure in the teaching of sylviculture and was forced on me from the moment I found myself placed in the midst of a bewildering variety of species and conditions, of which the European forester, with his half dozen or so of species having any general distribution in one and the same forest, his stereotyped seasons and his moist climate, has no conception. In India we want to turn out men who can use their eyes and will constantly endeavour to ascribe to their true cause or causes whatever comes under their observation. As to systems of regeneration and treatment we can at present merely do little more than borrow from our *confrères* in Europe. It is only when we have studied thorougly the habits and requirements of our numerous forest species and the peculiarities of the Indian climate as it affects the growth of forests, that we shall know how and with what modi-

fications to apply those systems in this country and what entirely new methods it will be necessary to introduce.

For the very same reasons that I have assigned the first place to a close and extended study of the conditions which determine the survival of the fittest in the struggle for existence in a forest crop, I have, in describing the methods of regeneration and treatment, attempted in every instance to give, even at the risk of laying myself open to the charge diffuseness and nedeless prolixity, detailed reasons for the measures and expedients recommended in each case.

One more point remains, on which some explanation is called for, *viz.* the size of the book. It will often be urged that a Manual written for the use of candidates for rangerships should contain only the broad outlines of sylviculture and that a work of 200 pages would have been sufficient for the purpose. Indeed I have sometimes been told that the instruction given in this book should have been conveyed in the form of dogmatic rules that must be followed without question. With this last dictum I am sure very few will agree, and I know that no one who has had any experience of teaching or of the management of an educational establishment of a technical character will ever assent to such a proposition. The forester's art is, perhaps, the one least capable of all of being reduced to rule of thumb, and least so in India, where for many years to come, until the conditions under which we have to labour have been thoroughly studied aud mastered, our work must still be chiefly of an experimental nature. Although the Forest School at present grants nothing higher than the Ranger's Certificate, it must not be forgotten that the better from among the certificated students will some day be in charge of subdivisions, and some of them even of small divisions, and whether as subdivisional or divisional officers, will have to carry out on their own responsibility the most difficult cultural operations.

And then it must not be forgotten that rangers hold in the Indian forest hierarchy the same administrative position as *gardes généraux* aud *oberförsters* in France and Germany respectively, although these latter ultimately supply the *personnel* for the controlling staff. Such being the case, I need hardly add that the highest authority in India ha laid it down that we cannot teach too much sylviculture at out School.

I owe my sincere acknowledgments to several gentlemen for criticism and advice received through the medium of the INDIAN FORESTER, and hope that I shall continue to be favoured with the

results of their long and varied experience as well as of that of my other colleagues. My own observations have necessarily been confined to a very limited part of the Empire, and the examples which I have been able to adduce in illustration of definitions and principles are, I know, often not only not the most appropriate, but frequently also misleading owing to the same species assuming a totally different habit or requiring totally different conditions to thrive in other surroundings. And not only this, but I fear that an insufficient study of species and their habits and requirements has often led me into important errors. But besides this, many experiments in forest culture have no doubt been carried out, of which no available record exists, but which would, if recorded, contribute in no slight degree to the immediate establishment of definite methods of regeneration or treatment specially applicable to the peculiar conditions of India. Some of these methods may be entirely new to the domain of sylviculture! To those who can help me in any way in increasing the value of the Manual when it comes to be published in its final form, I address an earnest prayer for their kindly co-operation. Relying on receiving this assistance, I have printed only a limited number of copies of this Draft in the hope that it may be possible to bring out the new edition early in 1890.

I have of course taken full advantage of the published works of European foresters; but I have derived most assistance from the admirable *Waldbau* of Dr. Karl Gayer, a work which, for philosophic treatment of every subject discussed in it, stands pre-eminent amongst the crowd of excellent works on European sylviculture.

As regards the technical terms employed, most of them have already received currency either here or in Great Britain. Some of them, such as 'exploit' and its derivatives, were hotly contested in the INDIAN FORESTER six years ago; but they have since received the sanction of the Forest Conference held at Dehra Dun in October 1886. At that Conference discussion was limited to terms expressive of ideas and operations connected with every day work. Latitude was, therefore, left me to use my own terminology where the Conference had not already settled the point. I am not satisfied with many of the terms employed, and if I had to write the draft over again, they would have to give place to others that now seem to me more appropriate. I would be the last person in the world to advocate the adoption of a stereotyped terminology,

still it is both convenient and necessary that all forest operations and ideas connected therewith should be known by names understood by every one.

The pages of the INDIAN FORESTER are open to every one and offer the best field we can have for discussing and settling disputed questions whether of terminology or forest work. Hitherto they have not been sufficiently utilised in this respect, the reason no doubt being the natural reluctance one feels to deal as well as to receive hard blows. But in the interests of science and of our own special profession we must cease to be too thin-skinned. How men of science in Great Britain can put up with, and do not mind receiving, hard knocks will be seen at once on reference to any number of the Journal "Nature."

In conclusion I must apologise for the innumerable typographical errors with which this Draft bristles. Publishing it in the manner already described, I could obviously avail myself only of small local presses, possessing neither reader nor efficient foreman. With the slender means at their command, they have nevertheless performed their work extremely well, and I owe them my best thanks for the patience with which they waited for "copy" when my hands were full of other work.

DEHRA DUN,
The 19th November 1888.

E. E. FERNANDEZ.

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Addenda et Corrigenda.

N. B.—The number of additions and corrections to make, especially the latter in respect of typographical errors, are so numerous that I can give below only the more important ones.

1. On p. 4 in Definition 34 insert the words "or shrub" after "tree."

2. *Page* 6, *line* 9 *from bottom*, Omit "selection-worked" and add "worked by jardinage" after "forests."

3. *Page* 7, *line* 7 *from bottom*. Insert "in a single operation" after "remove."

4. *Page* 16 *line* 13 *from top*. Insert "or hail" after "frost."

5. *Page* 54, *line* 9 *from bottom*. Add "also because the coldest air, being also the heaviest, flows to the lowest localities and collects there."

6. *Page* 78, *line* 10 *from bottom*. Insert "and covered with too thick a layer of dead bark" after "woody."

7. *Page* 83, *line* 4 *from top*. Add "on its accommodating nature in respect of soil and subsoil."

8. *Page* 83, *line* 5 *from top*. Read "to causes" instead of "to the causes," and insert after "injury" "such as, for instance, those."

9. *Page* 83, *line* 6 *from top*. For "Condition III" read "Conditions III, X and XI."

10. *Page* 83, *line* 9 *from top*. After "root-suckers" insert "on the case with which it recovers from wounds or any other kind of mutilation."

11. *Page* 83, *line* 10 *from top*. For "greater" read "special."

12. *Page* 83, *line* 22 *from bottom*. After "leader" insert "to early, abundant and frequent fructification."

13. *Page* 101, *line* 9 *from bottom*. After "India" insert "and to a much smaller extent in the Peninsula."

14. *Page* 116, *line* 3 *from bottom*. After "*growth*" insert "*consistently with their healthy and vigorous growth.*"

15. *Page* 129, *line* 21 *from bottom*. After "regeneration" insert "by seed."

16. *Page* 129, *line* 19 *from bottom*. After "*only*" insert "*if the new generation is to be merely a regrowth, the species should be able to coppice well,*"

17. *Page* 132, *line* 3 *from top.* For "*slip*" read "*cutting.*"

18. *Page* 134, *line* 5 *from top.* After "transplants" add "in general."

19. *Page* 142, *line* 10 *from bottom.* For "ridding" read "riddling."

20. *Page* 144, *line* 18 *from top.* For "2" read "3."

21. *Page* 147, *line* 6 *from top.* After "soil" insert "in the"

22. *Page* 148, *line* 18 *from bottom.* Before "hollow" insert "saucer-like" and omit "like a shallow bowl."

23. *Page* 149, *line* 11 *from top.* For "3" read "4."

24. *Page* 153, *line* 3 *from top.* For "both" read "more" and for "two" read "three."

25. *Page* 153, *line* 4 *from top.* Omit "and."

26. *Page* 153, *line* 8 *from top.* After "therein" insert "and (3) to render harmless or inert certain injurious substances present in the soil."

27. *Page* 154, *line* 12 *from top.* Continue "In the case of light soils full of organic remains, an admixture of clay besides giving them greater consistence, presents the too rapid exhaustion of the organic matters, which are retained by the clay and yielded up to the plants only in proportion to their requirements.

28. *Page* 162, *line* 18 *from bottom.* After "moreover" insert "where frosts occur or the climate is very damp."

29. *Page* 163, *line* 13 *from top.* After "to" insert "with the proportion of failures expected."

30. *Page* 165, *line* 18 *from bottom.* For "5" read "10" and for "3½" read "8."

31. *Page* 170, *line* 11 *from bottom.* For "18" read "19"

32. *Page* 170, *line* 2 *from bottom.* For "19" read "18."

33. *Page* 174, *line* 12 *from top.* For "hills" read "Himalayas."

34. *Page* 177, *line* 9 *from top.* For "boy" read "child."

35. *Page* 181, *line* 14 *from bottom.* For "ensures" read "ensues."

36. *Page* 188. Between third or fourth lines from bottom, introduce the last two paragraphs from page 189.

37. *Page* 193, *line* 3 *from bottom.* After "vigour" insert "and their ability to thrive growing close together"

38. *Page* 195, *first line at top.* For "170" read "182"

39. *Page* 195, *line* 9 *from bottom.* For "201" read 205."

40. *Page* 198, *line* 16 *from top.* For "230" read "306".

41. *Page* 203, *line* 10 *from bottom.* For "whey" read "they"

42. *Page* 214, *line* 9 *from top.* After "and" insert "can"

43. P 224, *line* 6 *from bottom.* Omit "south" and after "side" insert "of the sun."

44. *Page* 240, *line* 6 *from bottom.* For "82" read "81."

45. *Page* 245, *line* 3 *from bottom.* After "rains" insert "where these prevail."

46. *Page* 246. After line 18 from bottom introduce the following:—

"Where summer rains are weak or entirely absent, there obviously the sowing should be executed during the N. E. monsoon. In those localities there is fortunately no frost and the seedlings can, therefore, go on growing and establishing themselves during the mild dewy season which follows the close of the rains."

47. *Page* 252, *line* 9 *from top.* After "long" insert "oblique."

48. *Page* 253, *line* 4 *from bottom.* For "18" read "19."

49. *Page* 254, *line* 12 *from top.* For "strong" read "stony."

50. *Page* 257 *line* 4 *from bottom.* After "former" insert "also."

51. *Page* 258. After line 3 from top, insert new paragraph as follows:—

"Where the slope becomes gentle, short intermediate strips must be introduced in order to maintain as approximately as possible the fixed width of interval between two successive strips. Where the gradient becomes more rapid, every alternate strip must be discontinued with the same object.

52. *Page* 258, *line* 17 *from bottom.* Before "retard" read "owing to the afternoon sun."

53. *Page* 259 *line* 9 *from bottom.* For "iv" read "*d.*"

54. *Page* 261, *line* 12 *from top.* For "about 20" read "about 50."

55. *Page* 261, *line* 14 *from bottom.* After "up" read "and establish themselves."

56. *Page* 262, *line* 19 *from bottom.* For "never" read "always."

57. *Page* 262, *line* 17 *from bottom.* Before "terrace" read "middle of the broken."

58. *Page* 262, *line* 4 *from bottom.* Before "than" insert "actually sown."

59. *Page* 263, *top line.* After "sown" insert "either."

60. *Page* 264 *line* 13 *from bottom.* For "220" read "229."

61. *Page* 265, *line* 4 *from top.* For "width" read "depth."

62. *Page* 266 *line* 8 *from bottom.* For "256" read "264."

63. *Page* 267 *line* 21 *from bottom.* For "Gujranwala" read "Gujrat."

64. *Page* 271 *last line.* Omit "contour."

65. *Page* 274, *line* 58 *from top.* For "5" read "6."

66. *Page* 278 *line* 12 *from bottom.* For "sheltering" read "shelter"

67. *Page* 281, *line* 16 *from top.* Omit "and special fostering"

68. *Page* 281. Omit lines 6 and 7 from bottom.

69. *Page* 282, *line* 15 *from bottom.* After "to" insert "be"

70. *Page* 284, *line* 16 *from top.* After "one" insert "side."

71. *Page* 292, *line* 9 *from bottom.* After "India" insert "under the influence of the S. W. Monsoon."

72. *Page* 294, *line* 10 *from bottom.* For "280" read "287."

73. *Page* 295, *line* 20 *from bottom.* For "260" read "271-2."

74. *Page* 296, *line* 16 *from top.* For "d" read "d_2."

75. *Page* 297, *line* 12 *from bottom.* After "0·87 +" insert "d"

76. *Page* 297. In formulæ (ii) (iii) and (iv) for "d_2" read "d^2."

77. *Page* 300, *line* 16 *from bottom.* For "298" read "305."

78. *Page* 302, *line* 14 *from bottom.* For "covered" read "naked," and for "naked" read "covered."

79. *Page* 304, *line* 17 *from top.* For "becomes" read "become"

80. *Page* 308, *line* 19 *from bottom.* For "assimilating" read "transpiring."

81. *Page* 310, *line* 20 *from bottom.* For "v" read "vi."

82. *Page* 310, *line* 12 *from bottom.* After "of" insert "the"

83. *Page* 311, *line* 14 *from top.* For "vertical" read "verticel"

84. *Page* 317, *line* 17 *from top.* After "parent" insert "root."

85. *Page* 332, *line* 19 *from top.* After "go" insert "down."

86. *Page* 333, *line* 4 *from top.* For "320" read "326."

87. *Page* 335, *lines* 5 *and* 6 *from bottom.* For "keeping these two essential distinctions in mind" read "Nevertheless the younger the seedlings used are, the more nearly does planting resemble sowing, and the two systems become almost identical when mere germ plants are put out."

88. *Page* 339 *line* 2 *from top.* After "same" insert "time."

89. *Page* 342, *line* 16 *from bottom.* After "more" insert "or."

90. *Page* 343, *line* 14 *from top.* For "six" read "seven."

91. *Page* 344, *line* 2 *from top.* For "3" read "2."

92. *Page* 346, *line* 17 *from top.* After "of" insert "germ."

93. *Page* 347, *line* 15 *from top.* For "soon" read "sown."

94. *Page* 350, *line* 4 *from top.* After "area" insert "generally"

95. *Page* 353, *line* 16 *from top.* For "both sides" read "at least one side."

96. *Page* 354 *line* 8 *from top.* For "the only disadvantage" read "Only two main disadvantages."

97. *Page* 354, *line* 9 *from top.* For "is" read "are, firstly."

98. *Page* 354, *line* 10 *from top.* After "crop" insert "and, secondly, that if the strip runs through young forest, coppice-shoots will prevent regeneration by seed. Stool-shoots can of course be prevented from coming up by grubbing out all stools and large roots; but the appearance of suckers, if the species present produces them, is unadvoidable."

99. *Page* 355, *line* 4 *from bottom.* For "these" read "three."

100. *Page* 360, *line* 12 *from bottom.* For "iii" read "ii."

101. *Page* 366. After line 16 from bottom, insert the following:—

"In mixed forest the time for executing the seed-felling should be fixed principally with reference to the species that is the most difficult to regenerate."

102. *Page* 371, *line* 15 *from top.* For "370" read "362."

103. *Page* 375, *line* 4 *from top.* Before "thin" insert "stunted or."

104. *Page* 389, *line* 3 *from bottom.* After "certain" insert "extent."

105. *Page* 389, *last line.* For "it there to work" read "to work there."

106. *Page* 393, *line* 3 *from top.* For "116" read "117."

107. *Page* 394, *line* 8 *from top.* For "117" read "118."

108. *Page* 394, *line* 10 *from bottom.* For "118" read "119."

109. *Page* 397, *line* 17 *from bottom.* For "improvement" read "cleanings and."

110. *Page* 406, *line* 5 *from bottom.* After "coupes" insert "and run them in the directions recommended on page 258."

111. *Page* 414, *line* 12 *from bottom.* For "122" read "123"

112. *Page* 414, *line* 8 *from bottom.* For "123" read "124"

113. *Page* 416, *line* 20 *from bottom.* For "former" read "farmer"

114. *Page* 417, *line* 11 *from top.* For "they" read "their branches."

115. *Page* 419, *line* 8 *from top.* For "latter" read "former."

113. *Page* 416, *line* 21 *from top.* For "former" read "farmer."

114. *Page* 417, *line* 11 *from top.* For "they" read "the shoots forming the poll."

115. *Page* 419, *line* 8 *from top.* For "latter read "former,"

116. *Page* 426, *column* 1. After line 16 add "But, on the other hand, successful regeneration is entirely independent of the length of the rotation."

117. *Page* 426, *column* 2, *line* 18. Add "At the same time more or less long rotations are absolutely necessary in order to give time to the trees to attain fertility, to sow the ground, and, if necessary, also to nurse the young crop."

118. *Page* 450, *line* 9 *from top.* For "two" read "three."

119. *Page* 450, *line* 16 *from top.* Omit "and."

120. *Page* 450, *line* 14 *from top.* After "area" add "and, thirdly, the far greater obstacles against easy and quick firing offered by the innumerable small bushes, with which the trace must ultimately become covered when the seedlings subsequently produced have had time to grow up."

121. *Page* 450, *line* 17 *from top.* After "winds" add "Besides this, it will be seen from the first paragraph of the next sub-article that, whether traces are cleared or not of all woody growth, in nearly every case a second and even a third or fourth firing is unavoidable."

122. *Page* 452, *top line.* After "may" insert "not."

123. *Page* 462, *line* 14 *from bottom.* After "still" insert "Indeed, if the ridge be well-defined enough, the sharp crest would with advantage form one edge of the trace, especially if one side of the hill is very steep."

124. *Page* 465, *line* 18 *from top.* For "127" read "128."

125. *Page* 468, *line* 18 *from top.* For "windward" read "windstruck."

126. *Page* 468, *line* 20 *from top.* For "lee" read "lee".

127. *Page* 480, *line* 15 *from bottom.* After "trench" insert "The maintenance of a mixed growth is here also the most effective remedy to adopt

128. *Page* 481, *bottom line.* Omit "it".

129. *Page* 503, *line* 2 *from top-* After "does" insert "not".

130. *Page* 511, *line* 10 *from bottom.* For "50.07" read "56.07."

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CHAPTER I.

PRELIMINARY DEFINITIONS.

1. A TREE is any woody plant which carries up a single stem to a certain height above the ground, and which is besides capable of attaining a minimum height of 25 feet. The term "tree" includes arborescent palms and bamboos.

2. Trees, according to their size, may be classed as follows :—

I. LARGE trees, those which can attain a height of over 80 feet, *e.g.* teak, sal, deodar, *&c.*

II. MIDDLE-SIZED trees, those which attain a height of from 50 to 80 feet, *e.g.*, sissu, *Anogeissus latifolia*, babul, *Quercus incana*, *&c.*

III. SMALL trees, those which attain a height of from 25 to 50 feet, *e.g. Ougeinia dalbergioides*, khair, *Anogeissus pendula*, *Butea frondosa* *&c.*

3. A SHRUB is a woody plant which is incapable of attaining a greater height than 25 feet, and which generally branches at or near the base, *e.g.* the custard apple, *Bauhinia racemosa*, citron, *Randia dumetorum*, *Murraya Kœnigii*, the tea plant, *Mimosa rubicaulis*, *&c.*

4. A shrub that assumes the habit of a tree is said to be ARBORESCENT, *e.g.*, *Bauhinia racemosa*, *Murraya Kœnigii*, *&c.*

5. A woody plant, which never rises very much above the ground, is called an UNDERSHRUB, *e.g. Adhatoda Vasica*, the paper daphne, *Desmodium gangeticum*, *&c.*

From the proceding definitions it will be observed (*a*) that one and the same species may be a large tree in one locality, a middle sized tree in another and even a small tree in a third, according to the size it attained in the several localities ; (*b*) that what may be a tree in one place may be only a shrub or even an undershrub in another ; and (*c*) that a species, which is usually only an undershrub, may, under more favourable conditions, become a shrub, and *vice versâ*.

6. The term BUSH includes undershrubs and every degraded condition of shrubs and trees, in which the plants consist of numerous low spreading branches, such as the various species of *Zizyphus*, oaks, &c., when kept down by fires, grazing, constant lopping, &c.

7. The word SCRUB denotes a collection of bushes, shrubs, and dwarfed trees.

8. The collective name of BRUSHWOOD is given to all inferior shrubs, undershrubs, and other bush-like growth, such as *Mimosa rubicaulis*, the *Indigoferas*, *Blumea*, *Buddleia*, degraded forms of *Zizyphus*, &c.

The term *brushwood* is also used to denote the fallen twigs and small branches and stems of trees, shrubs and undershrubs. To avoid ambiguity, such small stuff may be called *faggot or fascine wood.*

9. The term HERBAGE includes all the growth in a forest which is not, or can never become, woody.

10. Plants which cannot rise to any height above the ground, except by attaching themselves as they rise to some extraneous support, such as a tree, shrub, post, &c., are called CLIMBERS, *e.g.*, *Bauhinia Vahlii*, *Spatholobus Roxburghii*, *Millettia auriculata*, *Celastrus paniculata*, *Butea superba*, the cane palms, &c.

11. The length of the stem of a tree under its branches is called its BOLE, and the mass of branches with their branchlets and leaves, *i.e.*, the whole of the tree above the bole, is called its CROWN.

12. The aerial stems of bamboos are called CULMS, the underground portion being the RHIZOME.

13. That portion of the stem which is left in the ground after a tree, whatever its age, has been felled, is called a STOOL. In popular language the word STUMP, besides including stools, also denotes the entire remaining portion of the bole of a tree that has been cut or broken off high above the ground.

14. EPICORMS are the twigs and the branchlets that develop on the boles of trees, when these have been suddenly exposed to the light.

15. Dicotyledons, as distinguished from the Conifers, which usually bear needles, may be termed BROAD-LEAVED species.

Two unimportant coniferous genera, *Dammara* and *Podocarpus*, have more or less broad leaves, while some dicotyledons, like *Casuarina*, *Capparis aphylla*, &c., produce no leaves at all, or, like the tamarisks, possess only scale-like or inconspicuous leaves.

16. HARD-WOODED trees, or simply HARDWOODS, comprise in a general manner all trees with tough and heavy wood, as, for example, sal, teak, the *Terminalias*, &c. Similarly the terms SOFT-WOODED trees or SOFTWOODS include all trees, the wood of which is more or less soft or spongy, such as *Bombax malabaricum*, the *Sterculias*, the horse radish tree, &c.

17. EVERGREEN trees are those, the leaves of which persist for at least one year, and do not all fall at the same time; while those, the leaves of which persist for a shorter time, and all fall within a few days, are termed DECIDUOUS. Evergreen trees are, therefore, never leafless, *e.g.* deodar, the pines and firs, mango, &c., whereas deciduous trees may either be leafless during a part of the year, as teak, *Terminalia tomentosa*, *Adina cordifolia*, or be never quite bare owing to the new leaves coming out while the old ones are being shed, as sal, *Schleichera trijuga*, babul, &c., generally, and sissu, *Hardwickia binata*, &c., frequently. Some may be evergreen in one locality and deciduous elsewhere, and *vice versâ*, *e.g.* *Quercus incana*, *Pinus longifolia*, &c.

18. A shoot springing up from a stool is termed a STOOL-SHOOT.

19. A young plant, which results directly from the germination of a seed, until it begins to lose its lower branches, is called a SEEDLING.

In this book the term *seedling* will often be prefixed as a qualifying word to the words *sapling*, *pole* and *tree* (for the meaning of which terms see Definition 21—23) to denote that the *sapling*, *pole* or *tree* in question has sprung up directly from seed.

By a further limitation the expression *seedling-shoot* will be synonymous with a stool-shoot springing up from a seedling cut back either artificially, or by fire, frost, or any other natural cause.

20. A ROOT SUCKER, or more simply SUCKER, is an aerial shoot given out from a root.

21. From the time that any woody plant begins to lose its lower branches until it has attained a girth of 12 inches more or less it is called a SAPLING.

22. Thenceforward, until it reaches its full length of bole, it is designated by the general term of POLE. For the sake of further subdivision, poles are termed SMALL or LARGE, according as they are under or over two feet in girth.

23. The pole stage of growth being passed, the plant becomes a FORMED TREE. When there is no risk of ambiguity, the word TREE without any qualification may be used in this sense.

24. When a sapling, pole, or tree is the immediate result of growth from the stool, the qualifying expression ON THE STOOL or ON STOOLS will be affixed, or the word STOOL prefixed to those terms.

25. A collection of shoots springing up from one and the same stool is called a CLUMP. The term *clump* is also applied to the collection of culms composing an individual bamboo plant.

26. When a sapling, pole or tree has grown up from suckers, the term SUCKER will be prefixed to those words.

27. A HIGH FOREST is a forest composed entirely or almost entirely of seedling trees.

The term SEED or SEEDLING FOREST would be more appropriate, but custom has given currency to the less accurate form of expression because, for various reasons, forests composed of seedling trees generally attain, or are allowed to attain, a greater height than the classes of forests referred to in the next definition.

28. A COPSE is a forest that is composed chiefly of stool-shoots, suckers, or culms. A COMPOSITE COPSE is one which consists in a large, or at least an appreciable, measure of seedling trees.

29. A tree is said to COPPICE well when it reproduces itself freely from the stool or from roots or from rhizomes. To COPPICE will also be used in an active sense, to mean to fell a crop with the object of obtaining a *regrowth* (See Definition 46) from the stools, roots or rhizomes of the trees felled. The individual stems composing this regrowth will be designated COPPICE SHOOTS.

30. To CUT BACK means to fell any plant, younger than a formed tree, by its base, and this with the object of obtaining, if possible, a regrowth from it. (See Definition 46).

31. To TOP OFF a plant signifies to remove its crown.

32. In POLLING a plant we may either top it off or remove only a part of its crown.

33. A POLLARD is a tree that has been polled.

34. By STOCK or CROP is meant the entire forest growth standing on any given area, and it is said to be COMPLETE for any age, when it is the maximum quantity which the soil can bear at that age.

35. To STOCK or CROP any piece of ground means to cover it with forest growth. The terms to RESTOCK or RECROP are used when the area in question has once been under forest.

36. A CANOPIED FOREST or CROP denotes a collection of trees, whatever their age, the crowns of which meet.

The LEAF-CANOPY is the mass of foliage formed by the crowns of the trees of a canopied forest. It is often useful or necessary to distinguish roughly the degree of closeness of this mass of foliage. Hence we may say (i) that the leaf-canopy is COMPLETE, when the branches interlace or meet every where and form an unbroken mass of foliage; (ii) that it is OPEN, when the crowns, although they meet, do not touch each other at every point; and (iii) that it is INTERRUPTED, when there are appreciable intervals between the crowns. In the first case only diffused sun-light can enter the forest below the mass of crowns; in the second case direct sun-light will also pass through, but in small, more or less uniformly distributed patches; while in the third and last case, the ground will be more or less completely exposed to the direct rays of the sun.

37. The DENSITY of a crop signifies the degree of closeness of the growth constituting it, and is hence a double function of the number of the component stems and the degree of completeness of the leaf-canopy.

38. When a forest is composed entirely, or almost entirely, of a single species, the other species, when any exist, being found principally only as brushwood or inferior undergrowth, it is said to be PURE; such are many of the numerous large stretches of babul, of tamarisk, of *Pinus longifolia*, of sal, of *Hardwickia*, &c.

39. When the forest consists essentially of two or more species growing together in varying proportions, it is said to be MIXED.

40. A GREGARIOUS tree is one which has a tendency to form more or less extended masses of pure forest, as, for example, sal, sissu, *Pinus longifolia*, &c. Such trees may also be called EXCLUSIVE; and as distinguished from them, those trees which only grow in mixed forest, may be termed SPORADIC or SOCIABLE, such as teak, *Dalbergia latifolia*, *Adina cordifolia*, &c.

41. A REGULAR crop is one in which the leaf-canopy, besides being complete, is formed by trees of nearly the same age and size. An IRREGULAR crop, on the other hand, is one in which the leaf-

canopy may or may not be complete, but is formed by trees of very various ages and sizes.

42. A REGULAR or NORMAL FOREST is one which consists of conveniently distributed regular crops, representing every stage of growth from the nascent plant to the tree fit for felling, and covering more or less equal areas or areas of more or less equal productive power. In the contrary case the forest is said to be IRREGULAR, or ABNORMAL *e.g.* all our present natural forests.

43. To EXPLOIT a forest or crop means to fell it in accordance with the principles of sylviculture. The noun EXPLOITATION corresponds to the verb just defined.

44. To REGENERATE a forest signifies to produce a new crop in place of the old exploited one; and the REGENERATION of a forest is accordingly synonymous with the substitution of the one crop for the other.

45. The regeneration of a forest or crop is said to be NATURAL or ARTIFICIAL, according as the new crop is entirely or for the most part the immediate consequence of the exploitation of the old one, or is due exclusively to means extraneous to, and independent of, the old crop and its exploitation.

46. The name REGROWTH will be specially given to the new crop obtained by coppice regeneration (*vide supra* under definition 29).

47. By ROTATION is meant the interval of years that elapses between the first appearance of a crop and its removal accompanied by the production of a new generation.

It is obvious that the existence of a rotation necessarily implies the more or less simultaneous appearance of the old generation, and a similarly more or less simultaneous removal of that generation and the appearance of the new one. There can hence be no rotation in the case of selection-worked forests.

48. Regeneration, broadly speaking, may be obtained (i), either from seed; or (ii), from stools, roots and rhizomes. When the former is the case, we have the HIGH FOREST REGIME; and when the new crop consists of stool-shoots, suckers or culms, we have the COPPICE REGIME. The régime hence depends on the manner in which regeneration is obtained.

49. With the same régime, different methods of culture may be adopted, each contituting a separate METHOD OF TREATMENT.

50. The various species composing a mixed forest may be distinguished into three several classes—PRINCIPAL, AUXILIARY and ACCESSORY.

51. The PRINCIPAL species (there may be one or more) is that which from the superior value of the produce it yields, and the general suitability of the prevailing conditions for its favourable growth, necessarily determines and regulates the rotation, régime, and method of treatment to be adopted in a forest.

52. Of the remaining valuable species well distributed throughout the forest, or capable of being generally introduced there, those are qualified as AUXILIARY, which, generally possessing different requirements from the principal species, utilize space both in the soil and in the leaf-canopy not occupied by the latter, and, in doing so, promote and improve its growth.

53. All other species, which are neither principal nor auxiliary, may be termed ACCESSORY. These are either too slightly distributed, or do not attain a sufficiently large size in the forest in question, or yield produce of too little value to influence in any permanent manner the working and treatment of the forest.

Thus in teak forest, teak would be the principal species; *Dalbergia latifolia*, *Terminalia tomentosa*, *Schleichera trijuga*, *Pterocarpus Marsupium*, *Anogeissus latifolia*, *&c.*, the auxiliary species; and *Sterculia urens*, *Odina Wodier*, *Cochlospermum Gossypium*, *&c.*, the accessory species. In special cases, however, in the present state of the market, *Dalbergia latifolia* and some other trees classed as auxiliary (e.g., *Hardwickia binata*, *Pterocarpus Marsupium*, *&c.*), provided they are abundant enough, may become principal species in company with the teak. Again in sal forest, sal would be the principal species; *Schleichera trijuga*, *Lagerstrœmia parviflora*, *Adina cordifolia*, *&c.*, the auxiliary species; and the *Tetrantherus*, *Phœbe lanceolata*, *Buchanania latifolia*, *Semecarpus Anacardium*, *Mallotus philippinensis*, *&c.*, the accessory species. Lastly in deodar forest, deodar would of course be the principal species; the spruce and silver firs, *Pinus excelsa*, *&c.*, the auxiliary species; and species of *Rosaceæ*, *Cornaceæ*, *Celastrineæ*, maples, hollies, &c., would compose the accessory class.

54. A COUPE is any area in which a felling or cutting has been or is to be made, and the produce obtained from the felling is collectively called the FALL or YIELD.

55. To CLEAR FELL a coupe means to remove the entire crop standing on that coupe, the corresponding operation being termed a CLEAR FELLING.

56. When a coupe is not clear felled, the trees left standing are the STORES, and collectively they may be termed the RESERVE. Such a coupe may be styled a STORED COUPE. When the reserve is spared long enough for a new forest crop to establish itself under

it, this lower crop constitutes the UNDERWOOD. As distinguished from *underwood* the term UNDERGROWTH is generic in its signification, and includes, besides the underwood, all brushwood, bushes, herbage, &c. standing under any loftier crop of trees.

57. A copse in which stores are left will thus be designated a STORED COPSE, and to distinguish from a *stored copse* one in which the coupes are clear-felled, this latter will be termed a SIMPLE COPSE.

As most of the stores become fertile before they can be felled, *stored copse* is necessarily a kind of *composite copse*. (See under Def. 28)

58. The seedlings, seedling-shoots, and saplings, which make their appearance before the standing generation of trees in a coupe are removed, will be termed the ADVANCE GROWTH.

59. A BLANK is any area inside a forest which is bare of trees.

60. A GLADE is a portion of forest in which the trees are scattered.

61. The term WINDFALL is applied to trees broken or uprooted by any cause whatsoever, generally by the wind.

62. HARDY plants are those which can endure more or less successfully exposure to drought and weather influences at all ages, *e.g. Zizyphus*, khair, sissu, &c. Those which require to be sheltered against one or more of these influences during their early years are termed DELICATE PLANTS, as, for example, teak, deodar, *Terminalia tomentosa*, &c.

63. All woody plants are light-demanding, though in different degrees. Those which maintain themselves alive under more or less dense shade are said to be SHADE-ENDURING, *e.g.*, deodar, sal, silver fir, *Mesua ferrea*, *Hardwickia binata*, *Dendrocalamus strictus*, *&c.*; while those which can only live in more or less direct sunlight are said to be SHADE-AVOIDING, *e.g*, teak, *Pinus longifolia*, *Pinus excelsa*, *&c.*

Shade-enduring plants may be *hardy*, like *Mesua ferrea*, *Hardwickia binata*, *Dendrocalamus strictus*, *Acacia Catechu*, *&c.*, or they may be *delicate*, like the silver fir, deodar, toon, *Terminalia tomentosa*, *&c.* Shade-avoiding plants are not necessarily hardy because they require free exposure to light; for instance teak, although extremely shade-avoiding, is very sensitive to frost.

64. A plant is said to be growing UNDER COVER, as opposed to its growing OUT IN THE OPEN, when it is vertically under the crown of another plant. Accordingly the COVER of a tree means the action exercised by its crown within the space below included in its vertical projection.

The influence of cover is very complex and is not quite the same for isolated trees as for a number of trees forming a leaf-canopy. In either case, under cover (1) direct sunlight is more or less excluded; (2) there is more or less shelter against insolation (3) radiation is more or less checked; hence (4) formation of dew is impeded but (5) risk of frost is diminished; (6) evaporation of soil-moisture is retarded; (7) little or no rain can fall directly either on the ground or the undergrowth below; but, on the other hand, (8) there is heavy drip from the crowns of the trees, due not only to rain but also to deposition of heavy dews, which drip not only shakes severely and thereby injures young seedlings, but also scoops out hollows in the soil and exposes the roots of such seedlings. All these effects are more marked in the case of canopied forest than in that of isolated trees. For instance, under a complete leaf-canopy few plants can receive sufficient sunlight for assimilation; and, in a cold region, the exclusion of the sun's heat-rays may shorten, in a very striking manner, not only the duration of the season of vegetation, but also the period of vegetative activity each day.

Besides the above-mentioned effects there is still another to be noticed in the case of canopied forest, viz; the exclusion, or, at least, tempering of violent or otherwise dangerous winds.

Hence *shade* is not synonymous with *cover*, since it is only one of the effects of cover and moreover moves with the sun, whereas cover is always stationary. Similarly the terms *cover* and *shelter* must not be confounded together, for shelter is partially an effect of cover and extends far beyond the area of projection of the crowns of the trees.

65. A plant is said to be SUPPRESSED or UNDER SUPPRESSION when its growth has been or is being injured by cover, and, conversely, one plant is said TO SUPPRESS another when it affects injuriously the growth of the latter by its cover.

66. A NURSE is a tree or shrub intended to protect against injurious weather influences young plants until they are sufficiently established to no longer require such protection. Hence TO NURSE signifies to perform the office of a *nurse*.

67. DORMANT or LATENT buds are those buds which, without losing the power of sprouting, remain quiescent and burst forth into leaf only under specially stimulating conditions, as when, for instance, owing to the natural or artificial curtailing of the existing foliage, there is a determination of the developmental energy of the plant to those buds.

Dormant buds consist of a woody stalk, which runs radially between the woody fibres of the axis that bears them, and of a herbaceous portion, the true bud itself, which in young shoots without a rhytidome protrudes beyond the bark, but in older shoots is generally concealed immediately under the rhytidome or the outer layers of the living bark, whence the synonymy of *latent*. These buds remain alive as long as their stalk is able to elongate and keep pace with the continually advancing concentric woody layers of the axis bearing them; but sometimes the herbaceous portion continues alive even after the stalk has ceased growing, being able to draw nourishment from the living bark in which they are embedded. Dormant buds not unfrequently multiply, often to a very great extent, by division of the growing point.

68. ADVENTITIOUS BUDS are those buds which take their rise at any place other than the axils of the leaves, and independently of the buds (termed NORMAL) which develop at those points.

Adventitious buds may be produced from the margins of leaves, as in *Bryophyllum*, or on a cut or broken section of any of the larger veins of the leaves, as in *Begonia* and *Gesnera*; but leaving out of consideration all such exceptional cases, which moreover do not concern the purposes of this book, adventitious buds may be said always to be produced by the cambium covering woody tissue.

Above ground they form only on wounds on the *callus* or swelling produced by the cambium, and, being there under the full influence of light, they can became dormant only under exceptional circumstances, such as extremely rapid development of the bark, great vitality of the cambium, the formation of very numerous buds, &c. In the ground wounds are not at all necessary for the formation of these buds, although they of course continue to be an exciting cause. Adventitious buds on roots are the sole origin of suckers, and are produced most abundantly on or near swellings, which prove the greater activity of the cambium there. Yearling seedlings of most of our broad-leaved trees and shrubs outside the higher regions of the Himalayas produce at the base of the stem, or immediately below it on the taproot, adventitous buds which we may for convenient reference term COLLUM BUDS. It is these *collum buds* which enable young seedlings to throw up new and generally stronger shoots as often as the portion above ground dies down or is cut back by fire, frost, &c.

No conifer produces adventitious buds below ground, and amongst our Indian species the silver fir alone perhaps produces them very occasionally above ground. Even amongst our broad-leaved species only a limited number develop them on the roots and above ground, but, as already said, the majority of them below the region of the oaks form collum buds.

69. ACCESSORY BUDS are those which in many species form close to the base of the regular axillary buds.

CHAPTER II.

STRUGGLE FOR EXISTENCE BETWEEN THE INDIVIDUAL PLANTS OF A FOREST CROP.

Of the plants produced in a forest only a comparatively small number can live the full term of their individual longevity. As they develop, besides extending vertically upwards into the air, and downwards into the soil, they spread out laterally against each other. But since their lateral extension, both in space and in the soil, is obviously limited to the superficies which the forest actually covers, each one naturally struggles to push out its neighbour. In this mutual struggle for existence various extraneous circumstances, such as insects, the action of man, grazing, &c., also intervene and exercise each its own influence on the longevity of the individual plants. Thus some of the plants are continually dying off and disappearing, only the fittest surviving until either natural decay and death overtakes them or the exigencies of forest economy require their exploitation. In order to illustrate the preceding statement, in the obvious absence of Indian examples, we will cite one from Germany, as given by Theodor Hartig and quoted by Karl Gayer. The crop experimented on was a full canopied one of the European spruce *(Abies excelsa DC.)*

"	"	40	"	"	"	"	"	1264	"	"	"	42	"	"	"
"	"	60	"	"	"	"	"	611	"	"	"	32	"	"	"
"	"	80	"	"	"	"	"	393	"	"	"	21	"	"	"
"	"	100	"	"	"	"	"	285	"	"	"	11	"	"	"
"	"	120	"	"	"	"	"	241	"	"	"	4	"	"	"

A study of the conditions which determine the survival of the fittest is thus extremely complicated by the variety of the inducing causes and by the different ways in which they act independently and conjointly one with another. Nevertheless it may be very greatly simplified by examining separately the principal aspects under which the struggle for existence may take place. In the first place, a forest crop may be either pure or mixed, and, in the second place the crop, whether pure or mixed, may consist either of plants of one and the same age, or of plants of different ages.

In the last case, the difference of ages may be slight, or it may be so marked that the component plants include every age from the individual just emerging from the seed to that fit for felling or on the point of attaining the natural term of its longevity. Between these two extremes there are, of course, an infinitude of various degrees of difference, but it is obvious that where the difference of ages is only very slight, we have practically the case of a crop composed of individuals of one and the same age, and where it is at all appreciable, the consideration of the instance in question would manifestly fall under the consideration of the larger case in which the component plants are of every possible age.

Hence it will be sufficient to consider separately the four following cases, taking them in the order of their increasing complexity:—

FIRST CASE.—That of a pure crop composed of individuals of one and the same age.

SECOND CASE.—That of a pure crop composed of individuals of all ages.

THIRD CASE.—That of a mixed crop composed of individuals of one and the same age.

FOURTH CASE.—That of a mixed crop composed of individuals of all ages.

SECTION I.

FIRST CASE.—Pure crop composed of individuals of one and the same age.

In this case the crop may consist either entirely of seedlings, or entirely of coppice-shoots, or of both seedlings and coppice-shoots.

When the crop is composed entirely of seedlings, as long as these are small and stand apart, or possess only or chiefly the tap-root, they do not impede the free development of each other either under or above ground, and the mutual struggle for existence begins only when their crowns or roots have ramified and attained sufficient lateral development to meet.

But if, coppice-shoots are present, this struggle for existence begins with the very appearance of the crop. In the first place, the several shoots of the same clump struggle with one another both for air and light and for the reserve material stored up in the parent stools, roots or rhizomes; and, in the second place, as the coppice-shoots begin to draw at once, from the moment they see the light, crude nutrient materials through a more or less extended root apparatus, which is at first a portion of the root-apparatus itself of the parent stool or plant, and afterwards an independent formation due to the shoots themselves, plants, whose crowns do not yet meet, nevertheless engage in a struggle for room and for sustenance in the soil.

The conditions which, in the case under consideration, influence and finally decide the struggle for existence are—

I. RELATIVE INNATE VIGOUR.—As far as seedlings alone are concerned, why some should possess more innate vigour than others, cannot always be explained. The larger or heavier seed does not invariably produce the stronger plant. In a seed-bed, containing the same soil throughout and treated under perfectly uniform conditions, some plants will be found to be larger, more vigorous and more hardy than others. Again, the larger plant is not necessarily the stronger one or the one more tenacious of life.

As regards coppice-shoots, their size and vigour do not always correspond with the apparent vigour and fitness of the parent stool or plant; nor are their size and apparent strength always a proof of their innate vigour. Moreover, stool shoots and suckers are, up to a certain age, much larger and stronger than seedlings of their own age, which, however, ultimately catch up the former and attain a higher stature and greater spread of crown. Besides this, coppice-shoots develop, soon after they come up, a ramified root-system of their own, which enables them not only to draw sustenance from soil situated at some distance from their stems, but also to invade the thin, weak, scarcely branched roots of young seedlings and thus starve them by appropriating, thanks to their greater vigour, the nourishment which the seedlings are in want of and which they would otherwise take up. In this last respect root suckers are the most to be feared by the seedlings.

II. GREATER SUITABILITY OF SOIL AND SUBSOIL.—In the case under consideration, as long as two neighbouring plants are quite young and small, the influence of soil and subsoil is of only slight

importance; since it is seldom, except in extremely rocky, stony, or uneven ground, that these elements of growth vary from point to point to a sufficient extent to influence differently their development. Nevertheless, if there is a very marked disparity of growth between them, and the soil is shallow and the subsoil unfavourable, the more vigorous plant, by pushing down its roots more rapidly and deeper into the ground, may receive a sudden check in its growth as soon as its roots have reached the subsoil. Again, if young seedlings and coppice-shoots are growing up side by side, an unfavourable soil and subsoil will give the victory all the more easily to the latter, especially if these be suckers, for these last will necessarily obtain a part of their nourishment from their parent-root, the tree producing which may be situated a certain distance off, where the conditions of soil and subsoil are better.

When the crop is old enough for the component stems to stand far apart, then, of course, variations in the soil and subsoil will always exercise a powerful influence on the struggle for existence.

III. DEATH, DISEASE, UNHEALTHY STATE, OR RETARDATION OF GROWTH DUE TO CAUSES EXTRANEOUS TO THE FOREST, *viz*:—

(a) Attacks of insects and other animals.—Some insects, especially the lignivorous kinds, attack chiefly or solely the weaker plants, particularly those that have already begun to decay, while others, like certain caterpillars, notably the various silk worms, and the larvæ of saw-flies and gall-flies and of certain *Coleoptera* attack all indifferently, and even rather affect plants possessing abundant well developed succulent twigs and foliage. Again, the lac insect prefers the strong juicy shoots of vigorous plants to the more or less dry, more or less hide-bound twigs of less vigorous individuals. Insects which attack the roots of plants will usually exercise no choice as between the strong and the weak, but mere accident might lead to their killing or keeping back the stronger individuals and enabling the weaker to survive. Cattle and deer, in rubbing themselves or their horns against trees, often peel off their bark and thus throw them back During the rains buffaloes, to keep off flies, put their heads into thick masses of foliage and, in agitating their heads. wrench and break off branches and even stems with their long horns. Elephants not unfrequently knock down trees and thus uncover overtopped plants or give lateral room for development to trees which had been pressed in before. Monkeys not only eat leaves and juicy twigs, but break off

much more than they can eat, and in jumping from branch to branch do great damage, especially when the species forming the crop replaces a broken leader with difficulty. Cattle, goats, and other herbivorous animals, while they do not spare weakly plants, still fall more greedily on strong ones with abundant, well developed, succulent twigs and foliage or roots ; but weak plants, growing in the midst of, or closely surrounded by stronger individuals, are often left untouched. The goat will often overlook small plants and stand up to one bearing leaves as high as it can reach. Besides the injuries already described, herbivorous quadrupeds may hurt or kill plants also by trampling them down, or by treading the soil into a hard pan, or by digging up or loosening with their feet the soil round them and thus injuring or, as often happens on steep ground, completely exposing their roots. Birds may peck off leaves, buds and young shoots, besides breaking them by perching on them. And so on. Hence it is not invariably, nor generally, the weaker plants that succumb to the attacks of animals.

(*b*) *Attacks of parasitic and epiphytic plants*—Some parasitic plants will, as a rule, attack only unhealthy individuals. Certain fungi, if they can only obtain a lodgement in some unhealthy or diseased part, will overrun an entire tree, however healthy it might otherwise be. Other fungi again, especially those that spread by way of the soil, will directly attack the most healthy trees. Purely epiphyllous fungi and those caulicolous species, which do not overrun an entire tree but cause only local injuries, will obviously influence the mutual struggle for existence more than those species which spread through every portion of the tree attacked and are thereby able at once to invade its immediate neighbours and thus rapidly involve them in the same doom. Woody parasites, like the mistletoe family, frequent weak and strong plants indifferently. The damage they do is usually confined to starving and killing the portion of the branch above the point at which they have fixed themselves. Some parasites, like the *Cuscuta*, overspread the entire crown of their host, sucking out the elaborated sap through their numerous haustoria, and in this manner not only rob it of its nourishment but also suppress a more or less considerable part of its foliage.

Epiphytic plants make no distinction between weak and strong. The smaller epiphytes can, of course, do no damage, while the larger ones, like the figs, hurt their temporary hosts by over-

topping them and thus suppressing their crowns and englobing their stems with their numerous coalescing aerial roots.

(c) *Injurious climatic influences—frost, drought, sunstroke, hail, rain, wind, snow, lightning, &c.*—Other conditions being the same, all plants will suffer equally from these causes, especially from frost, drought and hail. But as some plants will necessarily be taller or stronger or better lignified or more deep-rooted or in any other wise more tenacious of life than others, the various climatic factors will affect different plants differently. Nevertheless the victory will not always be for the stronger plant, for the weaker and lower plant may be sheltered by its more vigorous and taller neighbour, which, as often as not, may be so injured, especially by frost, as to allow the former to get ahead of it. The wind might uproot or break off an important limb of the strong tree; under the weight of superincumbent snow one or more large boughs might snap off; lightning might select the tallest or largest tree, and so on; and thus allow the weaker to conquer in the struggle for existence.

(d) *Conflagrations.*—The resistance offered to damage caused by fire will depend on the size and vigour and lignification of the plants, the number of dormant buds they possess, the size and height of their crown and the not too forward condition of the current year's buds when the fire occurs. But, as often happens, trees more favoured than others in the above respect may, from being situated near a mass of inflammable material or from any other accidental cause, be so injured as to throw them hopelessly back in the race of life. In the case of conifers which produce very few or no dormant buds and of species which coppice badly, the smaller plants will stand comparatively little chance of recovery. In the case of an evergreen species, *cœteris paribus*, the importance of forest conflagrations as an effective factor in the struggle for existence will be very considerably diminished, and, in the case of all other species, it will be slighter, the more nearly they approach the character of an evergreen.

(e) *Floods.*—Floods may injure plants in seven different ways: (i) by bending or breaking them, (ii) by straining or breaking their roots, (iii) by eroding the soil round their roots and thus leaving these exposed, (iv) by partially or completely submerging their crowns, (v) by rendering the soil too wet, (vi) by saturating the soil round their roots with injurious saline matter, and (vii)

by depositing a more or less thick layer of silt round or over them. In the present case we are concerned chiefly with the first five modes of injury, as the last must affect more or less equally all plants of the crop. Moreover the fourth and fifth modes of action have little or no effect on certain species, *e. g.* sissu, tamarisk, sundri, &c. The stronger and larger and better rooted plants will of course generally have the advantage, but a violent rush of water might lay down or strain and injure the roots of the large and vigorous tree, while its weaker neighbour, owing to the very fact that it opposes slighter resistance, might be bent down for the moment only, to rise up again as soon as the flood has passed and shoot up ahead of it.

Besides affecting the growth and stability of plants, floods may also wash away or bring in seeds, as well as influence, favourably or unfavourably according to the species concerned, their germination.

(*f*) *Action of man.*—The action of man is all powerful in the struggle for existence. If he is simply bent on satisfying his own immediate wants, he cuts out only what suits him, and he takes it out in the easiest and least expensive manner for himself. The relative size and vigour of the trees does not regard him in the least; he will often climb up into a tree to cut out only the portion of it that suits his purpose. The effect of his action on the growth of the surrounding or overtopping trees is no concern of his.

If he is interested in working out the trees with the greatest advantage to himself as well as to the forest, his action will be directed to modifying in the most favourable manner the natural struggle for existence. Here he will remove or keep back the larger plant to encourage its weaker neighbours; there he will fell the smaller one in order to give more growing room to the larger and more vigorous, and, therefore, more promising individuals; and so on.

However great or skilful the care exercised in felling, conversion and export operations, a certain amount of damage to the standing plants cannot be avoided. The smaller and weaker individuals will of course, on the whole, suffer most, but the fall of a large tree is more likely to break and throw back for ever plants with a rigid, more or less unyielding stem than those which simply get bent down for the moment until the fallen tree is removed.

(g) *Climbers.*—Climbers kill or at least unfit trees for the struggle for existence in six different ways—

(i) They may strangle the stems of their supports, narrowing year after year the channel through which alone the sap, pumped by the roots, can ascend. If the tree attacked forms a heartwood, it must ultimately die of sheer inanition.

(ii) As the climber and its victim increase in diameter, the increasing pressure on the bark of the latter necessarily forces the elaborated sap to descend obliquely and spirally instead of vertically, and thus gradually diminishes the amount of nourishment conveyed to the under portion of the tree. The roots thereby suffer most, and their consequent debilitation and contraction obviously reacts with increasing effect on the crown above.

(iii) Climbers also bend down by their weight the stems of their victims.

(iv) When they get up into the crowns of their supports, they invade and overspread those crowns, which cannot, therefore, bear their full quantum of foliage, and are also thereby impeded both in their lateral and upward development, especially in the latter.

(v) They distort the boles of their supports, and thus necessitate the removal of these latter by the forester.

(vi) When the same climber attacks two trees, the fall of one of these might bring down the other.

All these various injuries will of course be great in proportion to the weakness and small size of the individual attacked.

IV. COMPLETENESS OF THE LEAF CANOPY.—It is obvious that the plants, which have free space round and over them, will keep on growing and survive, while others, taller and stronger than they but less so than their immediate neighbours, succumb under this cause. The struggle will evidently be severest on the side where the leaf-canopy is closest.

Every species whatsoever, whether shade-enduring or shade-avoiding, can form a denser leaf-canopy when young than at a later age, and its need for light increases with advancing age; for the larger the amount of nourishment to be elaborated is, the larger will be the sum total of light required. In a canopied crop, as long as a tree is still growing in height, light

reaching it from above suffices, if not to enable it to grow luxuriantly, at least to keep it alive and to draw it up rapidly. But when the phase of upward growth is practically over and the full length of bole has been attained, that is to say, when the upper portion of the crown has lost its exceptional vigour and can no longer either replace by new organs the lower branches which have hitherto died and fallen off without any constitutional injury to the tree or assimilate sufficient nourishment for its roots, the tree can live only on the condition that the lateral portions of the crown contribute their share towards its nutrition. Thenceforth a keen struggle for lateral development begins with its neighbours, and the tree gains or loses the victory according as it is stronger or weaker than they. Thus the leaf-canopy becomes gradually sparer, until, at a very advanced age, varying with the species concerned, the individual trees stand completely isolated.

The more favourable the soil and locality are, the closer together can the trees stand at any age; for the spread of their roots will be in inverse proportion to the abundance and concentration of food in the soil. And, in general, the presence of sufficient moisture in the soil and in the atmosphere, combined with the requisite temperature, increases the ability of a species to form a dense leaf-canopy at all stages of growth, by encouraging the development of foliage, and hence the spread, depth, and thickness of the crowns.

All species form a denser leaf-canopy the longer the period of vegetation in each year is, for the total effect of light will be in proportion to the duration of its influence and the degree of exposure of the trees to its action; hence the total effect being the same, the shorter the time of its action, *i. e.* the shorter the season of vegetation, the further must the trees stand apart, and *vice versâ*.

Lastly, the greater the intensity of sunlight at any place is, the better can a given species tolerate cover overhead; and conversely, the less intense the light, as, for instance, on northern aspects, in mist and fog-clad regions, under generally clouded skies, &c., the further apart will the trees grow, and the more will they object to being overtopped. Moreover at high elevations, owing to the clearer and rarer atmosphere there, light, whether diffused or direct, has more effect on vegetation than at lower altitudes; hence the higher within due limits a place is above the sea-level, the denser will be the growth of any given species.

If the species composing the crop is shade-enduring, like the deodar, silver fir, *Quercus incana, Terminalia tomentosa*, &c, or one which at all ages interlaces branches, like the khair, species of *Zizyphus, Anogeissus pendula, A. latifolia*, &c., the struggle for existence is a long and severe one. On the other hand, when the constituent species is like the *Pinus longifolia* or the *Hardwickia binata*, the first shade-avoiding from its earliest years, and both abhorring the interlacing of branches, the struggle is a brief one, and the weaker and overtopped plants are soon thrown out of the race. And, in general, the severity and duration of the struggle for existence is in direct proportion to the tendency of the trees to grow close together, whatever the cause or causes that tendency may be due to.

V. SPREAD OF ROOTS (INCLUDING THE RHIZOME).—Some species, such as sal and *Prosopis spicigera* develop a main root which works its way down vertically to a considerable depth; while others, after sending down a short taproot that ultimately dies, produce only lateral roots, which start from just below the base of the stem and run along close and more or less parallel to the surface of the ground. These latter, as distinguished from all other plants, may be called *surface feeders*, since they depend for their sustenance entirely on the upper layers of the soil. Between these two extremes come all the remaining plants, the main roots of which diverge at different angles from the vertical or horizontal. It is evident that the more nearly a species assumes the character of a surface-feeder, the earlier does the struggle for existence begin, for, in the contrary case, a plant can go down to lower depths for its food if it has to yield to lateral pressure from its more powerful neighbours, and can thus draw its nourishment from within a smaller area of ground. The richer and moister the soil is, the more limited will be the area from which a given plant can obtain all the nourishment it requires, and hence the less tendency will the plant have to spread out its roots, and, for one and the same density of the crop, the less intense will be the struggle for existence.

But whatever the system of root development peculiar to any species, for several years at first, their number varying with the species, the seedling consists of only a single main root and a small crown of a few leaves and hardly any or no branches

During this phase of development the young plant can do nothing more than push down this main root beyond the reach of ordinary drought, being unable to absorb and, therefore, also to elaborate more nourishment than what suffices for this purpose. In this way the taproot gradually elongates and strengthens itself by throwing out a few small branches until, having taken a sufficient hold of the soil, it is able at once to meet a much larger demand from the crown above. This is the meaning of the phrase of "a plant establishing itself". The seedling is now able to make a rapid start upwards, and the roots, better nourished than before by the very much stronger and constantly expanding crown, take a vigorous lateral extension. With stool-shoots and root-suckers it is otherwise; their roots are, for a time at least, the roots of the parent tree itself. In the case of stool-shoots most of these roots soon die, since the shoots cannot obviously elaborate enough nourishment for them; so that a great abundance at first is followed by a rapid shrinkage, and this again by a gradual expansion as the shoots continue to develop their own roots, the rapidity of expansion being directly proportional to the rapidity of growth of the shoots. Under any circumstances, unless the crop is very open, the mutual contact between the root systems of the various individuals is always maintained. In the case of root-suckers identical results follow if the parent tree has been removed or broken off near the ground; otherwise there is never a contraction but, on the contrary, a continual expansion of the root system.

VI. AGE OF CROP.—As already mentioned at the beginning of this Section, the mutual struggle for existence in a crop composed entirely of seedlings does not commence for some years, until the plants are old enough to have spread out their roots and crowns so as to have attained mutual contact, although of course every plant individually has to contend against causes of injury extraneous to the forest or arising out of location in an unfavourable soil. When coppice shoots form a portion of the crop, the commencement of the mutual struggle is of course contemporaneous with the appearance of the crop itself. But whensoever this struggle begins, it is always at first of a comparatively mild character, but becomes rapidly keener and keener while the trees are going through the most active period of the phase of longitudinal growth, during which certain individuals so outstrip their neighbours as to completely suppress them. As the activity of longitudinal development slackens, so does the mutual struggle for existence become

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less and less severe, the combined result mainly of the diminishing number of stems and the more equal race between the survivors. But when the phase of active lateral development is reached, the struggle, in spite of the absolutely small number of trees left, again increases in intensity, although its nature is now considerably changed. In the former case there was a very marked disparity in the heights of the competing trees, which, being moreover small, had a comparatively weak hold of the ground, the consequence being that those overtopped were so hoplelessly beaten, that they easily succumbed under the victors. But in this second phase the struggle is between mostly large masterful trees, possessing great powers of resistance, and none of them able to gain the easy victory attainable, as in the first phase, by loftier stature; hence the smaller percentage of casualties during this time, notwithstanding the extreme severity of the struggle. But towards the close of the period of active lateral development, the number of stems having so diminished that each tree has nearly all the room it requires, the mutual struggle rapidly becomes less keen until it ceases altogether, when with advancing years the vitality of the survivors gradually fails, the crowns no longer develop their original wealth of foliage, but on the other hand contract (consequent on the drying up and disappearance of, at first, the smaller branches and then the larger limbs), and the trees die one by one from sheer old age. The natural process here described is well illustrated by Th. Hartig's example cited on page 11.

VII. RELATIVE LONGEVITY ACCORDING TO ORIGIN OF INDIVIDUALS.—Here we have obviously no concern with the relative longevity of individuals having one and the same origin, as, for instance, of stool-shoots alone or of seedlings alone, and so on, for that longevity is only a convenient expression for the combined result of the simultaneous and joint action of all the various conditions discussed under the present case. What we have to do is only to distinguish between the relative longevities of seedling trees, trees on stools, and suckers. Culms may be left out of account altogether, for in the tribe of the bamboos, which are the only culm-producing plants we have to deal with here, the culms are no better than the branches in the crown of any ordinary tree. Stool-shoots and suckers indeed are also branches by origin, but they ultimately enjoy a separate individual existence. Although accurate observations are wanting, it is certain that seedling trees are the longest lived, and that the younger the parent stool or

tree is, the more nearly do stool-shoots and suckers approximate seedling trees in longevity. Owing to their origin stool-shoots are generally not so longlived as suckers, and the disparity is always greater the older the parent stool is, for in proportion to the size of the stool will always be the risk of unsoundness in the butt, and, after a certain age, also the want of vigour of the shoot.

VIII. RELATIVE RAPIDITY OF GROWTH.—As already explained in several places above, seedlings always go through a longer or shorter period of waiting, during which they are establishing themselves; while, on the other hand, stool-shoots and suckers push up rapidly as soon as they are produced, attaining in their very first year the same size as seedlings from 5 to 20 years and upwards old. This, so to say, exaggerated development they owe to the large amount of reserve matter stored up in the parent stool or tree. Suckers, if the tree which produced them is still standing, maintain this rapid growth at the expense of the parent until they have developed a complete root system of their own; but stool-shoots soon exhaust the reserve matter of the parent stool, and then, being left entirely dependent on themselves, their growth generally falls off and in a few years they are overtaken by the seedlings and passed by them. It is obvious that the younger the stool is, the more nearly will the mode of growth of the daughter shoots resemble that of a seedling. Culms differ from all the rest in that they complete the whole of their development in height as well as in thickness within a few weeks of a single season.

Examples of the First Case.

Natural instances of the First Case may be found in the tamarisk forests of Sindh and in some of the babúl forests of the same province; also in bamboo forests, the constituent species of which flowers gregariously. Another striking instance is offered by copses of a single species that are clear-felled, in which, practically all the stool-shoots spring up the very first season following the exploitation. With them must of course be included the forest standing on land at one time subjected to the barbarous system of cultivation known under the various names of *jhūm* (Assam-Bengal), *taungya* (Burma), *son, hái* (Shan country), *kíl, khíl, karái* (N. W. Himalayas), *dhaya, bewa* (Central India), *kutukár* (Tamil), *punokar* (Canarese), *kumri* (Southern Marathá Country), &c., which consists in clearing and burning off all the vegetation on the ground, raising one or two crops on the ashes, and then taking up

fresh areas, not to return until the forest is again old enough to yield a sufficient supply of ashes. Such are many of the pure teak copses of the Sathpuras, &c.

As artificial examples of this First Case we may quote plantations formed of a single species.

SECTION II.

SECOND CASE.—Pure crop composed of individuals of all ages.

In this case there is never, as we have seen frequently occur in the one just treated, any lull or relaxation in the mutual struggle for existence between the various plants composing the crop. New individuals are every moment being produced under or in immediate contact with those already on the ground, and every stage and phase of growth is constantly represented, provided of course unfavourable causes entirely extraneous to the forest do not prevail to bring about the gradual ruin and disappearance of the forest growth as such. The main point of difference between the present and the preceding case is the practically unlimited disparity between the ages and dimensions of the various individuals of the crop, which disparity affects to a more or less considerable extent the action of all the other causes influenceing the progressive growth of the crop. The determining conditions for the survival of the fittest are, therefore—

I. Relative innate vigour.—The importance of this condition here is not so great as in the First Case, for Condition VI (which see) will generally quite nullify it. Nevertheless greater age is not necessarily a criterion either of greater vigour or of greater debility, for the coppice yearling shoot will, as a rule, be always very much more vigorous than a seedling several years old, and an aged tree may not unfrequently be more tenacious of existence than another in the prime of life.

II. Greater suitability of soil and subsoil.—In the remarks made under this head in the preceding case, it was explained that in bad soils and subsoils combined disparity of size may give the victory to the less advanced individuals. That remark may be repeated here with greater emphasis, since, in the present case, the disparity between a plant and its neighbours may have no practical limit. When the subsoil is impenetrable

sheet rock or clay, or is impermeable to water, or, on the other hand, is so permeable as to be entirely waterless so far as vegetation is concerned, the younger plants may be able to live on, while the older ones wither, decay, or die off as soon as their roots reach this unfavourable subsoil, having it may be, in the meantime, while struggling to establish themselves, improved it for the younger growth. So also when the soil and subsoil are very poor, the older and larger plants, requiring a larger sum of nourishment than the soil can afford, may become stag-headed and thus open out the leaf-canopy for the younger individuals. Where, the subsoil not being utterly bad, the soil above is very stiff or very wet, the older plants will generally possess the advantage, since with their more woody and stronger roots they can resist breaking and ejection during the successive contraction and expansion of the soil under the influence of alternations of drought, moisture and frost, and with their larger root and leaf systems, guaranteeing a sufficiently rapid absorption and transpiration, escape wet feet.

III. DEATH, DISEASE, UNHEALTHY STATE OR RETARDATION OF GROWTH DUE TO CAUSES EXTRANEOUS TO THE FOREST, *viz.*—

(*a*) *Attacks of insects and other animals.*—Insects attack young and old alike, but unless these pests are very numerous or very voracious, the older plants, provided they are not yet in their decline, will obviously possess greater powers of resistance than those much younger, especially if the insects in question are phyllophagous. As against other animals hurtful to vegetation, greater age gives a very marked advantage, so much so that plants above a certain size are perfectly safe against most of them.

(*b*) *Attacks of parasitic and epiphytic plants.*—These plants are no respectors of age; but it is evident that the older a tree is, the more likely is it to survive the attacks of all such plants other than fungi.

(*c*) *Injurious climatic influences—frost, drought, sunstroke, hail, rain, wind, snow, lightning, &c.*—The extent of difference between neighbouring plants as regards size and vigour being, in the present case, practically unlimited, the remarks made under the First Case on this head apply here with greater force. Young plants coming up under lofty trees, will be perfectly safe against frost, hot and cold winds, and snow, and, to a great extent, also against drought and hail; on the other hand, the drip from the trees above might prove hurtful or even fatal to young seedlings.

Again, the older individuals, with their large and long roots extending every where in the direction of moisture, will be secure against the severest and most protracted drought.

(*d*) *Conflagrations.*—The remarks made under this head in the First Case apply here in their fullest force. Even in the severest fire very few large trees are killed outright and the majority of them suffer only a comparatively slight retardation of growth due to the scorching of the foliage, the death of some of the buds and of the more herbaceous twigs and shoots, and perhaps the charring of some portion of the bark right up to the cambium. Indeed in *Pinus longifolia* forest the flames do not always attain the crowns, so that it is not uncommon in tracts of that species to see, after a fire has passed through, the poles and larger individuals simply blackened for a few feet up their boles, but otherwise apparently uninjured. On the other hand, the smaller individuals suffer severely, and the extent of the injury increases in geometrical progression as their size diminishes, being greatest in the case of species that cannot coppice.

What has been said in the preceding paragraph refers only to the vitality and growth of the plants, not to their soundness. Forest fires never fail to produce unsoundness, but unsoundness by no means necessarily implies want of vitality, for a tree may be in the full vigour of growth and yet be quite unsound.

(*e*) *Floods.*—There is not much to add to what has been said under this head in the preceding case. The extent to which floods may injure the various plants of a crop will be directly proportional to the difference between their respective sizes, the advantage being in nearly every case on the side of the larger individual. This statement requires no explanation as regards the effect produced by the mere violence of the rushing flood-waters and the covering of silt brought in by them. As regards the injury which plants may sustain from submersion, it is evident that the younger and, therefore, the smaller of them will be completely submerged during the most ordinary floods, and the damage will increase in geometrical ratio with the length of time the floods last. Thus is accounted for, to a very great extent, the small proportion of young plants, even of species inhabiting only flooded lands, in tracts subject to frequent inundations. As regards the excess of moisture in the soil accompanying a flood, it is evident that the younger individuals, if the species is a denizen of marshes, will suffer more than their older neighbours, from being unable to transpire as

rapidly, and also from having their root system comprised within the upper layers of the soil, *i. e.* those most affected by the flood waters. This latter reason also explains why the larger trees resist the effects of saline deposits longest.

(*f*) *Action of man.*—Here also little can be added to the remarks made under this head in the First Case. It is during the period preceding the sapling stage that plants possess their maximum power of recovering from injuries caused by felling, conversion and export operations, because it is during this time that they are most flexible and elastic, and shoot up in the most vigorous manner from below any point at which they may be broken or badly damaged. After this period they rapidly lose their flexibility, and, but in a less degree, also their elasticity, and, if they get broken, they have a tendency to develop a tuft or brush of shoots instead of at once throwing out a strong leader. Moreover the larger the size of the injured tree, the larger will be the wound and the quicker will be the progress, and the more weakening the nature, of the consequent decomposition.

(*g*) *Climbers.*—The action of climbers has been fully explained in the First Case; but one additional remark must be made here. As a rule, climbers can get up into young trees with their thin stems and low branches more easily than into the lofty crowns of their older thick-boled well-grown neighbours, and once a young tree is attacked, it is hopelessly doomed, not only as a potential piece of timber, but also as one of the strugglers in the race for life. Nevertheless if a climber can, by means of neighbouring small individuals, get up into the crown of a large overtopping tree, it will maintain all or nearly all its foliage on the same level as the crown of that tree, and thus leave some of the overtopped stems unmolested, while keeping back their overtopping rival. In this way may be explained the freedom from climbers of many young individuals in dense forests, although the climbers may be almost as numerous as the trees themselves.

IV. Completeness of the leaf-canopy.—Light is not necessary for germination, for the young seedling develops, and can even make a certain amount of growth, by means of the reserve matter stored up in the seed. But once that reserve matter has been utilised by the seedling, this latter must die if it is unable to assimilate food for itself; in other words, it cannot do without light. While the seedling is still small and makes but little progress, and, on that account, wants but little food, illumination

more or less feeble suffices; but as it grows on and its wants increase, the requisite amount and degree of illumination necessarily increases in proportion. Similarly, coppice shoots, as they push on and increase in size, require increasingly effective illumination, although, as compared with seedlings of their own age, they must obviously receive, because of their more rapid early growth and larger size at first, a considerable amount of light almost from the very moment that they make their appearance. The requisite degree of illumination will depend on the size of the parent stools, roots or rhizomes. Thus, whereas small seedling-shoots (see Definition 19) scarcely require more light than true seedlings of their own size, the strong shoots that come up on well-nourished stools of middle age will be almost as exacting as saplings and poles nearly three times larger than themselves. But while both seedlings and coppice shoots require an ever increasing amount of light as they push up, they can survive for a certain time on very much less than this, the length of time varying with the degree of endurance of shade of the species in question and with the age of the plants. Thus deodar and silver fir, both remarkably shade-enduring species, may survive under a very dense leaf-canopy until they are 40 years old and upwards, whereas seedlings of *Pinus longifolia* and teak, which are very partial to light, cannot persist under fairly dense cover for more than 10 to 15 years, and teak stool-shoots for barely 5 years. But if young plants can survive under cover up to a certain age, it does not follow that they will retain as long the full power of recovery on being admitted to the influence of light. After a certain time the cambium becomes weakened owing both to the very restricted transpiration and assimilation, and to the increasing pressure on it between the growing woody layers on the inside and the hard, dry bark on the outside, and the result is that the plants become hidebound. If they are broadleaved, they may gain new vigour by being cut back, otherwise, although they will continue to live, they will never, under the most favourable circumstances afterwards, come to anything.

Due weight being given to the important considerations developed in the preceding paragraph, all the remarks made under this head in the First Case hold good also here, and even apply with greater force. Only a single additional observation need be made in this place as a pendant to the proposition enunciated there, that young plants of every species whatsoever are more shade-enduring than their older fellows, and it is that this

circumstance is most marked in the case of species that are very partial to light, like teak, *Hardwickia binata*, *Pinus longifolia*, sal, &c.

V. SPREAD OF ROOTS (INCLUDING THE RHIZOME).—This is a much more important condition than is very generally supposed, its most striking effects being erroneously attributed to other causes, notably the absence or presence of sufficient light. On the ground immediately surrounding a large sal tree, although many sal seeds germinate every year, hardly any of the numerous plants produced are observed to survive. This result is at once ascribed to insufficiency of light due to the cover of the large tree, notwithstanding that the tree in question may be quite isolated, unbranched up to more than 40 feet, and narrow-crowned. The true reason is to be sought in the dense and thick mass of roots, root-fibres and root-hairs of the large tree, which form a close network occupying the soil to a very considerable depth, defying penetration by the thin weak roots of the seedlings, and monopolising, thanks to its very much greater absorptive power, all the nourishment that the soil can yield.* The same phenomenon may be observed with all species, more markedly with some than with others. We can now understand why the injury sustained by seedlings under overtopping trees is greater in direct proportion to the depth, spread and density of the crowns of these trees, since a deep, broad and dense crown means a proportionately deep, close and wide spread of the roots and a proportionately great absorptive power.

The preceding special remarks should be read in connection with all the observations of a more general character made in the First Case under this head.

VI. INDIVIDUAL AGES.—In the preceding case we could consider only the effect of the changing age of the entire crop, since all the individuals were essentially supposed to be more or less of one and the same age. Here, on the contrary, the age of the entire crop is a term that is excluded by the very hypothesis of the case, and we have as an effective substitute the condition which heads this paragraph.

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* If further proof is required to show the utter groundlessness of the reason generally ascribed, we have only to look at the frequently flourishing young sal under the really dense cover of trees of other species possessing very much heavier crowns than the sal, but which have a different root system, thereby allowing the roots of the young sal to get through into soil not completely monopolised by other plants.

In the preceding paragraphs we have necessarily already considered from most aspects the effect produced by a difference of individual ages. These it would be entirely superfluous to repeat here. Only one principal point, and that of a totally general nature, remains to be noticed. From the time when a tree whether seedling or coppice shoot, makes its appearance, it goes on increasing in vigour and tenacity in geometrical ratio until a few years after it has passed the phase of maximum lateral development. Then a stationary period of more or less short duration follows, succeeded by a decline at first very gradual and afterwards increasing in geometrical ratio until death supervenes. In this last phase the crown contracts and becomes spare, letting light pass through at various points, and the root system contracts in proportion. Progressively with this process the younger surviving neighbours, hitherto overtopped or pressed in laterally, now gradually come on and finally, having acquired superior vigour, push into and through their old rival, forcing it to contract still more its diminished foliage and roots and ultimately hastening its death.

VII. RELATIVE LONGEVITY ACCO ORIGIN OF INDIVIDUALS.—All the remarks made under in the First Case are to be accepted here in their fullest sense. It is, therefore, evident that seedlings of appreciably greater age may be able to outlive stool-shoots and suckers, especially the former. Hence seedlings, once they have attained a sufficiently large size, have nothing to fear from companions of their own species differently derived from themselves.

VIII. RELATIVE RAPIDITY OF GROWTH.—Whatever has been said under this head in the First Case applies here without any reservation. It hence follows that seedlings are always exposed to be kept back or completely suppressed by stool-shoots and suckers, even though these may have no present existence, as long as they have not yet entered the phase of rapid upward growth and are still small enough to be caught up by these latter. Suckers are of course very much more dangerous than stool-shoots by reason of their continuously rapid growth, which suffers no relaxation almost until they attain their full height. For this reason also suckers may get the better of stool-shoots older than themselves. But it is evident that culms enjoy the greatest advantage of all in this respect, for, since they complete the whole of their upward development within a few weeks, other individuals,

to be quite safe from them, must necessarily have attained a considerable or even very great height, varying from a few feet to 100 feet and more, according to the species of bamboo concerned.

GENERAL REMARKS.

From the considerations developed in the discussion of the two preceding cases it is obvious that, other circumstances being the same, the leaf-canopy will always be more complete and the soil be better protected when the individual ages of the trees composing a pure crop are different than when they are uniform or very nearly uniform; for as soon a tree from any cause whatsoever disappears or gets broken, there are always a great many others to take its place or fill up any gap it leaves, since new plants are being continually produced. Thus with a noticeable difference of individual ages, the production of the soil will be greater, the trees will be straighter and taller, the fertility of the soil better maintained and improved to a higher degree, and the preservation, amelioration and regeneration of the crop more easily and more certainly secured.

Examples of the Second Case.

Instances of the Second Case are abundantly offered by large tracts of *Pinus longifolia* forest in the North-West Provinces and the Punjab; of babul and of sissu in Northern India, in Sindh, and in the Northern Deccan; of khair and of sal in Northern and Central India; of *Hardwickia binata* in Central and Southern India; of *Mesua ferrea* in Assam; of *Acacia rupestris* and of *Anogeissus pendula* in Rajputana; of *Acacia modesta* in the Punjab; of teak in Central India and Bombay; &c., &c.

SECTION III.

THIRD CASE.—Mixed crop composed of individuals of one and the same age.

In the two preceding cases we had to deal with pure crops, the individuals of which necessarily differed from each other only in respect of comparative vigour, size and age. In this, the Third Case, a very complicated element enters, for no two species, however similar to each other they may be, can possess the same habit of growth, or the same requirements as to soil, climatic influences and locality, or the same longevity or vitality, or the same liability to damage from various causes, or equal facility of

reproduction, &c. Here we have to consider not merely the struggle between individual and individual, but also that between species and species; hence the conditions which determine the survival of the fittest plants of the crop are much more numerous, and are extremely complicated by their acting simultaneously, and often more or less nullifying each other or producing joint effects that sometimes defy analysis. Their consideration is also all the more difficult, as they run one into another, and a thorough examination into the working of any one of them is seldom possible without some consideration of some one or more of the rest. In the immediately following pages, therefore, many points will often be anticipated before they are fully discussed in their proper place. Moreover minor details will be omitted in order not to trespass beyond the limits that must be observed in writing an elementary work such as this Manual is intended to be.

The various conditions bearing on the struggle for existence in the present case will be studied under the following seventeen main heads:—

I. INNATE VIGOUR.—Though not less important here than in the two preceding cases, this condition has not so far reaching an effect as those which follow, for these latter may, much more so than what we saw in the Second Case a mere difference of individual ages do, totally nullify any advantage possessed by a plant in respect of innate vigour alone. This will become rapidly obvious with the progress of the present discussion.

II, GREATER SUITABILITY OF SOIL AND SUBSOIL.—The influence of this condition is extremely great, and is sometimes the sole effective cause of a forest being more or less pure. Thus, for instance, in the eng *(Dipterocarpus tuberculatus)* forests of Burma the laterite keeps out, or restricts very considerably the distribution of, other species. So in India where teak and *Terminalia tomentosa* are companions, the proportion of teak increases as the amount of clay in the soil diminishes, and *vice versâ*, so that in strongly clayey soils the latter species remains almost pure. Again in the very few instances in which sal and teak can grow side by side, sal, possessing many advantages, usually drives out teak; but generally there is a clear line of demarcation between the two species, marked by an increase in the proportion of clay beyond the point up to which sal can thrive. Then again, in the *Boswellia thurifera* forests of Central India that

species becomes pure in ferruginous soils. The more or less pure growth of sissu is also due to the special nature of the soil. And so on. Even in a limited area the soil may vary from point to point in respect of one or more of its principal properties—physical and chemical composition, depth, hygroscopicity, compactness—all these various differences favouring one species at the expense of another, besides producing marked differences in the vigour of plants of one and the same species.

On shallow soils resting on a compact subsoil, surface-feeders will thrive better than trees that send their roots deep into the ground; and, similarly, species that throw up suckers than others not possessing that faculty, which, indeed, is increased in such soils.

The soil also influences reproduction to a very considerable extent. If it is hard or caked at the surface, or dry, species producing seeds which germinate with difficulty (*e.g.*, teak, &c.), or are so large that they are either washed away or insufficiently covered (teak, the *Terminalias*), stand little chance against such of their companions as produce smaller seeds that are caught in little crevices or depressions (*Anogeissus*, *Rhododendron*, *Pieris*, &c.), or seeds that germinate more readily (sal, &c.). Moreover in such soils, species, the young seedlings of which develop a strong taproot, capable of forcing itself into the ground (*e.g.* sal, teak, *Buchanania latifolia*, &c.), are bound to prevail over their less favoured companions. In loose, free, moist soil the victory will obviously be little dependent on the size of the seed.

III. DEATH, DISEASE, UNHEALTHY STATE, OR RETARDATION OF GROWTH, BROUGHT ON BY CAUSES EXTRANEOUS TO THE FOREST, *viz.*—

(a.) Attacks of insects and other animals.—The remarks made under this head for the first two cases are equally applicable here. Besides this, we know that with many insects certain species are characteristic of, and limited to, certain kinds of trees, and that some others have a decided preference for certain kinds usually avoiding all the rest as long as these are abundant enough; that cattle and deer will greedily devour the foliage of some kinds and leave others untouched; and so forth. Thus, for instance, it is not uncommon to see every teak leaf over large tracts of the Central Provinces eaten up by a certain species of caterpillar in the space of a few days, while the foliage of the various companion species is entirely free from the pest. Similarly, the foliage of sal

is attacked and more or less completely devoured over large areas by the larva of a certain species of insect *(Tinea)*. Again, a borer *(Cerambyx)* often attacks young teak shoots, piercing the wood up to the pith, where it lodges, and thus either kills the portion of the shoot above the wound, or stops or retards its growth, or allows it to be easily snapped off by the wind, In some of the forests in Saugor, in the Central Provinces, young *Stephegyne parvifolia* have no chance of getting up, as the tender annual shoots are devoured by deer as fast as they come up. So in the Himalayas, *Quercus incana, dilatata, and semecarpifolia* can never rise above a mere bush where grazing and lopping for fodder are unrestricted. For many miles on both banks of the Ganges near Hardwar *Odina Wodier* is kept back by elephants, which eat the young wood; and bamboo would suffer still more were it not for its production of new culms every year. In some places in the outer Himalayas near the Ganges, where sal is not abundant, that species is rapidly losing ground owing to numerous individuals of it being knocked down by elephants, which eat its bark medicinally.

As regards cattle generally, there are some species, for the leaves and young twigs of which they show a natural partiality, and when these are available, they will seldom browse off other plants that even come in their way. Thus, for instance, in tracts of *Hardwickia binata* that species, bringing out, as it does, its new flush of leaves in April, is the only plant that yields green fodder in the parched hot season and its leaves are then greedily devoured by cattle; but during the rains, when there is an abundance of other and more congenial food, cattle, as they graze along, will generally carefully avoid *Hardwickia* seedlings. This also explains the general immunity of sal from injury by cattle. On the other hand, cattle may acquire a tutored taste for certain kinds of fodder, which they would under ordinary circumstances eschew. Thus calves in Nimar in Central India are often taught to feed by having bunches of teak leaves, conspicuous by their size, hung up in front of them; and when they grow up, they continue to relish teak leaves, buffaloes having often been known to bend down with their bodies saplings of that species in order to get at the leaves.

A few words may be said here regarding the relative destructiveness of our common domestic herbivorous quadrupeds. The least harmful of all are those of the equine class; they possess incisors in both jaws and, therefore, bite off clean, and their undivided hoof cuts into the soil very little. All the rest,

the pig excepted, have incisors only in one jaw, so that they do not bite, but tear and wrench off; seedlings with short roots or growing in soft soil they may pluck out bodily by the roots. All of them, except camels, have cloven hoofs, the sharp moveable segments of which cut up the soil on slopes. In the latter respect goats and sheep are most to be feared, as they can frequent the steepest ground, and goats are more dangerous, on account of their very much more active habits, their marked bark-eating propensities and their standing up to leaves and shoots as high as themselves. The weight of the buffalo and his natural inert nature, which leads him to prefer crashing through a bush to moving to one side in order to avoid it, renders him more objectionable than the cow. Pigs, being grubbing animals, besides killing outright young plants of species they eat, break and expose the roots of a great many others; but they are also useful in that they loosen the soil, triturate and mix up with the mineral soil the undecomposed upper layer of vegetable detritus, and destroy rats and insects. Camels are dangerous on account of their great reach and the manner in which they seize a twig and, by tugging at it, let it slip through their mouths, leaving behind the leaves. Arranged in descending order of destructiveness we have (1) the goat, (2) the sheep, (3) the camel, (4) the pig, (5) the buffalo, (6) the cow and (7) horses, mules, and donkeys.

(*b*) *Attacks of parasitic and epiphytic plants.*—All the remarks made under this head for the First Case apply also here. Moreover parasites are nearly always selective, preferring some species to others, or living exclusively on a single species; and so, although to a much less extent, with many epiphytes. Thus the *Arceuthobium Oxycedri*, as far as is known, grows in India only on *Juniperus excelsa* and *Pinus excelsa*, gradually overspreading the plant on which it has once taken root, and often killing the branch or the entire tree.*

(*c*) *Damage caused by climatic influences.*—Under this head we will understand only the injury suffered from the causes in question by *individual plants*, irrespective of whatever influence they exercise on the *general growth* of each species considered collectively. The consideration of that influence would introduce a much larger question, the extreme importance of which requires

* Precise information under this head is wanting in India, and more careful and extended observations are urgently called for. At the present moment our knowledge with reference thereto is extremely meagre.

that it should be treated under a separate major head (see Con. X below). This reservation being borne in mind no further remarks are called for here than what have already been made on this subject under the first two cases.

(d) Conflagrations.—The various degrees of resistance offered to the effects of forest fires by the different species composing the crop will depend on a great many circumstances, the principal of which are the following:—

(i) The evergreen or deciduous nature of their foliage.—It is evident that under a constant leaf-canopy the moisture of the soil is maintained at its maximum and there is a minimum amount of combustible undergrowth on the ground. Consequently, if fire entered, and it generally could not do so except in dry soils, and then too only during the driest months of the dry season, the flames would not rise high, and the crowns of poles and large individuals would be safe or, at least, suffer little injury. But, on the other hand, under an evergreen leaf-canopy the layer of accumulated dead leaves and other vegetable detritus will be thick, and, although the fire fed by it will generally only smoulder, yet the heat evolved will be proportionately intense and very destructive for young growth. The preceding remarks are of course true only if the evergreen trees stand in groups and are, therefore, able to form the constant leaf-canopy implied; but isolated trees will be no better off than if they were deciduous, except in that, if they have attained the age of fertility, a large proportion of the undergrowth under them, consisting of their own progeny, will also be evergreen and check the violence of the fire below. In this last case groups must ultimately be produced, if other and contrary conditions do not prevail, and the groups must steadily extend themselves. From the preceding remarks it is obvious that the more nearly a species is evergreen, the greater is the advantage it possesses over others which are in leaf during a shorter period of the year. This fact is brought home very forcibly by observing the almost insurmountable barrier opposed to the progress of a conflagration by belts of the *Bauhinia* climber. Foresters in Central India, in fire-tracing operations, know how to turn to account masses of *Ougeinia dalbergioides* flanking their fire-lines, for that species is in full leaf at the time of those operations and no guide or check line need be cleared along their edge, as the fire from the trace cannot spread into them. Many sal forests are to a great extent self-protected, the sal being very nearly an evergreen.

(ii). The season of leaf-fall.—Some trees shed their leaves in the cold weather, so that by the time the season of forest fires arrives, the dead leaves have scattered and settled into a close mass, which naturally can not flare up as high as the loosely packed leaves that fall at the beginning of, or during, the latter season. On the other hand, if fire sweeps through a crop before all the trees have shed their leaves for the year, those still retaining them will generally have less combustible matter under themselves than all the rest that have already completed their leaf-shedding, the difference being most marked if those are evergreen and these deciduous. In any case, the least dangerous time for a forest fire to occur is usually just before a tree has begun to lose its old foliage.

(iii) The season of appearance of a new flush of leaves.—It is obvious that if a fire occurs when a new flush is in the process of coming out, the tender succulent leaves must, as a rule, be entirely destroyed, unless, as in the Himalayas, especially in conifer forests, the flames do not rise high enough to reach the crowns. The trees that thus lose their first flush of leaves, can evidently put forth only a comparatively poor second flush, and, if the destruction of the first flush is repeated in this manner year after year, they must, other circumstances being similar, be easily beaten in the struggle for existence by their more favoured neighbours. The same result would follow, but of course in not so marked a manner, if the conflagrations broke out only after the new flush of foliage had completely come out. On the other hand, should a fire occur before the buds of a tree had begun to swell up preliminary to bursting forth into leaf, it is obvious that their vitality, owing to their containing at that time a comparatively small quantity of moisture, would be less easily destroyed than if they had begun to swell up, since they would then contain their maximum of moisture.

Forest conflagrations, when they occur while any species is in a state of vegetative repose, are always followed by a sudden outburst of activity, which is naturally greater in proportion to the nearness of the normal season of activity of that species. Greater premature activity thus resulting, provided excessive injury has not been sustained, is obviously advantageous for the species in question as compared with its equally injured rivals, if there is sufficient moisture in the soil and the weather, until the normal season of activity arrives, is not unfavourable.

(iv) Thickness and vitality of the bark.—Some species, like

sal, *Pinus longifolia, Diospyros Melanoxylon*, &c., form early a thick bark, which may be fibrous and corky as in sal, or principally corky as in the two other species just named. This thick bark is obviously a very great protection to the larger individuals, and a still greater one to seedlings and saplings, whose small diameter exposes them to be easily killed as far as the pith itself. The advantage of possessing a bark that reforms readily over burns, cracks &c. is too evident to require proof. *Pinus longifolia* and *Boswellia thurifera* are endowed with this characteristic in a very remarkable degree, large wounds being completely closed up in an incredibly short time. It is the possession of this quality and of a thick corky bark that to a great extent enables the pine in question, although a conifer, to resist the effects of forest fires almost as well as broad-leaved trees. It is unquestionable that the presence of a gummy or resinous secretion increases the vitality of the bark.

(v) The number and vitality of dormant buds.—Dormant buds enable plants to bring out a new flush of leaves, or to renew any damaged portion of their crowns, or even to shoot up again when they have been burned down to the ground. The larger their number is and the greater their vitality, the larger will be the number that will survive and be able to repair the injuries suffered in a conflagration. All the broad-leaved species possess dormant buds right down to the collum of the root in the soil, and these buds live on for a great many years: more in the case of some species than in that of others, but always for a great many years. On the other hand, dormant buds in conifers are the exception not the rule, and amongst Indian conifers the *Pinus longifolia* and yew are perhaps the only species which possess true dormant buds; but even these are situated at a comparatively very few irregular points on young wood, being soon overtaken by, and disappearing under, the advancing concentric layers of wood, and being really numerous and possessing great vitality only until the young pine has formed its first true verticel. Very young deodar, and larch before they begin to shoot up rapidly, apparently possess dormant buds, but the side shoots they produce, by which they are so often enabled to replace the upper injured end of the main axis, are simply due to an abnormal development of the bundles of needles, which bundles are of course abortive branches.

(vi) Ability to form adventitious buds—Few species possess this faculty to a sufficient extent to give them any appreciable

superiority over their neighbours, but the few which do enjoy it in a marked manner, like *Boswellia thurifera*, are of course placed at a great advantage.

(vii) Vitality of the root-collum.—This property is intimately connected with, and is to a great extent an effect of (iv), (v) and (vi), but even the action of those qualities is dependent on a special characteristic to be possessed by the species in question. Thus, for instance, both sal and *Terminalia tomentosa* coppice as freely as teak until an advanced age, but the last only is able, up to 40 or 50 years of age, to throw up shoots from the collum of the root just below the surface of the ground. Nearly all broad-leaved species in India are able to shoot up again from the root collum during the first few years, thanks to the collum buds they produce; but they do so with various degrees of vigour, and it is evident that those which enjoy this faculty longest are preeminently the best adapted to resist the effects of fire.

(viii). Ability to throw up suckers.—Species which possess this faculty, rather benefit than otherwise by forest fires, for, although recurring conflagrations may prevent or retard their upward growth, the number of stems representing them is augmented, not only when an existing individual is burnt, but even when it is simply weakened, the tendency to throw up suckers being directly proportional to the extent of injury suffered by the aerial portion of the parent plant. Witness the numerous large patches of almost pure *Ougeinia dalbergioides* in the dry forests of the Sathpuras. The remarkable gregariousness of *Boswellia thurifera* is, in a great measure, due to its being able to produce suckers.

(ix) Density of foliage.—The denser the crown of a tree is, the smaller will be the quantity of the undergrowth under it to feed the flames and draw them up into the overhanging crown. Thus *Hardwickia binata*, with its open foliage, encourages a close undergrowth in the immediate vicinity of its trunk, the consequence being that, when fire comes in, the flames rise up to the summit of the highest crowns, which, notwithstanding that they may be quite green, blaze up like tinder.

(x) Spread and depth of crown.—An ample and deep crown will have the same effect as density of foliage. Besides this, it will tend to ensure the safety of the summit, or the most sensitive and important portion, of the crown.

(xi) Height of crown above the ground.—The advantage of greater height of crown is too obvious to require discussion.

(xii) Ability to form at once a strong new leader on the death of the original one.—Greater facility in this respect is a very conspicuous advantage, for it means little or no retardation in upward development, a question of the first importance during the most critical phase in the life of a tree forming part of a leaf-canopy.

(xiii) Season of flowering and fructification.—The fatal effects of a conflagration occurring during the process of flowering and fructification are self-evident. Most of the gregarious trees of those parts of India, where forest fires are a regular annual scourge except when special precautions are taken, flower after fires have passed through, and complete their fructification before the next fire season arrives, *e.g.*, teak, *Pterocarpus Marsupium*, *Boswellia thurifera*, Khair, *Hardwickia binata*, *Terminalia tomentosa*, *Anogeissus latifolia* and *pendula*, *Dendrocalamus strictus*, &c.

(xiv) Season of fall of seed.—It is a truism to say that if fire comes in after the seed has fallen, there is very little chance of any of it escaping.

(xv) Ability of seeds or fruit to escape complete destruction by fire.—Fruit with a hard or thick pericarp, like that of teak, *Terminalia Chebula* and *belerica*, *Zizyphus xylopyra*, &c, can stand a good deal of scorching without losing their germinative power. Hard dry fruit, even without a thick pericarp, like that of *Terminalia tomentosa* and *Arjuna* also resist well. On the other hand, moist or oily seeds with a thin protective covering, like those of *Bassia latifolia*, sal, *Pinus longifolia* &c., are killed most easily of all. Very small seeds, like those of *Celastrus senegalensis*, most of the grasses, &c., often escape by being able to get into small crevices or cracks, &c.

(xvi) Slope of ground.—A tree on a steep bank or slope will naturally suffer more than others on less inclined ground, not only from the flames mounting higher as the fire rushes uphill, but also by reason of the mass of dry twigs and other inflammable matter caught by the trunk on the upper side.

(xvii) Size and consistence of leaves and quantity shed.—The needle-shaped leaves of conifers naturally settle and form a closer mass than the large, flat leaves of broad-leaved species, which,

therefore, flare up higher and quicker, and give out a more intense, if not so prolonged and steady a heat. Moreover these leaves are easily carried up in a burning state up to more than a hundred feet by the uprush of hot air and thus increase the risk of the green crowns catching fire. The conifers have, in almost every case, also another advantage, and that is that, as their leaves persist for two years and upwards, they shed at any one time only a portion of their foliage. The thicker and more woody leaves are, the greater and more prolonged will be the heat they will give out in burning.

(xviii) Inflammability of bark and dead leaves and wood due to presence of oil or resin.—In this respect conifers stand at a very great disadvantage. It is a notorious fact that in a forest fire more green standing individuals of some species are burnt down than of others.

(xix) The time when any fire in question occurs.—On this will depend the quantity and dryness of the combustible matter present, and consequently also the absolute severity of the fire.

(xx) Exacting nature of the various species as regards richness of the soil.—Fires consume all the fallen leaves and other vegetable detritus. It is true that in the ashes they leave behind they render *at once* available the mineral constituents of plant-food present in that detritus; but that is no compensation at all for their dissipation of the organic elements, the continued presence and transformation of which into new compounds would besides have enabled the soil to absorb an additional quota of such constituents from the atmosphere. Forest soils, unless the dead leaves and other disjecta are swept away and removed as soon as they fall, are never wanting in the mineral constituents of plant food, and nothing save actual special manuring can restore to the soil what fires take away from it. Besides consuming all organic matter in the upper layers of the soil and in its dead vegetable covering, forest fires also bake its surface into a hard crust and glaze the surface of silicious stones and rocks, thereby delaying very considerably their disintegration under weather influences. It is thus evident that species that can thrive or at least maintain a vigorous growth in poor soils are favoured by the occurrence of fires in their struggle with their more exacting neighbours. See also conclusion of second paragraph under "*Floods*" on page 42.

(xxi) Exacting nature of the species in respect of moisture in the soil.—It is obvious that this circumstance can affect

only such species as bring out their new flush of leaves or are in leaf during the season of forest fires. The extent to which individuals of such species will be influenced by fires sweeping through the crop will depend on the quantity of their roots spreading within the layers of soil affected, as far as regards the moisture they contain, by the fire.

(xxii) Size and shape and easy germination of their seed.—Whatever low growth exists on the ground at the beginning of the rains, checks, in proportion to its closeness, the washing away of the seeds that are shed by the trees overhead. The more frequent and severe forest fires are, the sparser will be this growth and hence the greater will be the advantage possessed by species producing seeds, which, being small or flat, are at once caught in crevices in the ground or do not easily roll or slip away, or which, germinating readily, anchor themselves forthwith; and this advantage will be the greater, the more sloping and smoother the surface of the ground is.

(*e*) *Floods.*—All the remarks made under this head in the First Case have a more extended application here than even in the Second Case, since the difference between plant and plant in the present case may be practically unlimited in every respect except age. It will be perceived that ability to produce suckers increases in a very remarkable degree the resistance any given species can offer to the destructive effects of floods. Whether floods bend, break or strain the aerial or subterranean portions of a tree, or erode the soil, or bring in a deposit of silt, species producing suckers will ordinarily not only maintain themselves, but even increase their own proportion in the crop, and this the more easily, the more destructive, within certain limits, the floods are.

In the First Case, the saturation of the soil by floods with saline substances was, as we have seen, of slight or no importance in the *mutual* struggle for existence. Here this circumstance acquires its fullest significance, for whereas some species may be killed outright by the introduction of such substances, others may thrive as well as before, while a third class will suffer various degrees of check in their growth. Thus babul is almost the only species that can flourish in reh soil. In the Kheri Trans-Sarda forests in Oudh, floods of the adjoining Soheli river have recently killed out all the khair in the fire-protected lowlying block near Dudhua, while new sissu are coming up in the newly deposited silt. Before fire-conservancy was introduced, the grass was all burnt

in the hot weather, and, no obstacle being offered, the annual inundations subsided without leaving behind any appreciable quantity of the fine silt which has now killed the khair.

(*f*) *Action of man.*—All previous remarks on this head, except what is purely referable to a mere difference of ages, have a much wider application here, for there is much more room for selection in a mixed than in a pure forest, and the action of man there must, on that account, have a considerably more far-reaching as well as intensive influence. Before the introduction of conservancy, teak was cut in the Central Provinces for the meanest uses and, except for fuel and for a few other special purposes, there was no demand for any other species. In the interior of the Himalayas, deodar is up to the present the only tree removed on any considerable scale. Centuries of dhaya have given an easy predominance to teak over large areas in Central India. In fact the action of man, steadily directed with a single unswerving aim, may controvert the laws of nature to the utmost point to which they may be defied. Indirect consequences of his action are also manifest in forests, as, for instance, the injurious effects of sulphurous fumes emitted from neighbouring smelting furnaces.

The extent to which a species can resist injuries resulting from felling, conversion and export operations will depend—

(i) On its faculty of shooting up again from the collum of the root, or of throwing up suckers ;

(ii) On the firmness and strength of its roots ;

(iii) On the strength and elasticity of the trunk and branches;

(iv) On its ability to re-form at once a strong leader, when the original one has been broken or killed ;

(v) On its ability to replace sufficiently early a lost important limb ; and

(vi) On the vitality of the bark, *i.e.*, its readiness to form and close over wounds and bruises.

All these points are self-evident, and require no explanation.

(*g*) *Climbers.*—The remarks made under this head in the First Case apply with equal force here. Besides this, it may be added that climbers are in no sense selective as regards the species of tree along which they rise above the ground, except that those which climb only by means of tendrils or adventitious roots will seldom be found on trees with smooth or exfoliating

bark, such as *Homalium tomentosum, Boswellia thurifera*, &c. Usually climbers are confined to rich or at least moist soils, and are hence peculiarly destructive to species that affect those soils.

IV. COMPLETENESS OF THE LEAF-CANOPY; RELATIVE DENSITY AND SHAPE OF CROWN, AND RELATIVE CAPABILITY OF PERSISTING UNDER OR PUSHING UP THROUGH COVER.—It will be noticed that the second clause of this heading is additional to what appeared in the two previous cases. Its necessity is evident, for with only a single species in the crop, all the plants are necessarily equally able or equally unable to persist under or push up through cover overhead; whereas the moment a second species enters the crop, the relative ability of the two in this respect becomes a most important element in the mutual struggle for existence, and has hence to be considered. Moreover, the relative density and shape in question of the crown of any species regulates, to a considerable extent, its proportion in a mixed crop.

As a rule, the denser the foliage of a species is, the more shade-enduring will young individuals of it be; for greater density of foliage generally, if not always, means that, owing to the superior shade-enduring nature of the species in question, more of the buds produced at the axils of the leaves have sprouted than could have continued their development if the species had been less shade-enduring. Instances of the rule are deodar, silver fir, mango, *Buchanania latifolia, Eugenias*, laurels, *Terminalia tomentosa, Diospyros Melanoxylon, Stephegyne parvifolia, Mimusops indica, Pongamia glabra*, bamboos, the holly, *Quercus incana*, &c., &c. Such species have obviously, irrespective of any other condition, a great advantage over such of their companions as are more shade-avoiding, the crowns of which would then generally be more open. Whereas young individuals of the former class could always ultimately get up into the leaf-canopy above, which end would be rather facilitated than otherwise by the more open overhanging trees of the other class acting as nurses, the young of these latter would not only be subject to suppression by the leaf-canopy above, but would also be elbowed out by their more shade-enduring companions in the undergrowth. Thus where sal and *Pinus longifolia* meet, although pine seedlings are produced in abundance, they are very soon choked up and overtopped by young sal, which gives them no chance of existence except where the soil is too poor and dry for it. Similarly, although deodar and the silver fir are both preeminently shade-enduring species,

still the superiority which the latter possesses in this respect, gives it a complete mastery over the other on moist aspects.

Some trees there are, which although after a certain age they cannot flourish except with their crowns free on every side, yet, during their early years, are able to stand a great deal of shade. A very remarkable instance of this is the *Hardwickia binata*, seedlings of which will persist under dense and even low cover for ten years and upwards. Again, young *Pinus longifolia* seedlings are not unfrequently to be found, if not absolutely vigorous, still full of vitality, under low, bushy *Quercus incana*. Nay teak itself will live for years as undergrowth in forests of medium density, consisting of bamboos, *Pterocarpus Marsupium*, *Terminalia tomentosa*, *Cochlospermum Gossypium*, *Boswellia thurifera*, *Hardwickia binata*, *Anogeissus latifolia*, &c. In this way a young plant that is overtopped by a large individual of another and more shade-enduring species may survive long enough to see the latter disappear from one cause or another, and then be able to push on unchecked.

Again a tree standing in immediate contact with, and on the same level as, another belonging to a more shade-enduring species may, if it is still in the phase of active lateral development while the other has passed it, be able to elbow it out of the crop or at least maintain an equal struggle with it.

Since every species can stand more shade, the brighter the sun is, or the longer the season of vegetation, or, within certain limits, the higher the elevation, it naturally follows that the vigour with which it can struggle with other associated species will vary with latitude, distance from the sea, aspect, altitude, configuration of the earth's surface, clearness of the atmosphere, &c.; so that it may succumb in one place, while merely holding its own in another, and even conquering in a third, its rivals being in all three places the same. Thus in southern latitudes *Anogeissus latifolia* is a very strong species in low situations, on level ground, on northerly aspects and even at the bottom of valleys, while in Northern India it is confined chiefly to southerly slopes and comparatively high elevations. Again young sal in the Nandaor valley in Eastern Kumaon is remarkably more shade-enduring on southerly than on northerly slopes. When the season of vegetation is very short, as at very high altitudes, all species become extremely light-demanding and the forest growth at those elevations is always very open. The more rapidly a species completes its

annual quantum of growth, that is to say, the greater its vigour of assimilation is, the better is it adapted to compete successfully with other species equally or more shade-enduring: e. g., the teak, which in many parts of Central India completely develops its new annual shoot in three months; the culms of the various species of the bamboo tribe attain their full length in a few weeks; and so on.

Species also become more shade-enduring with increasing humidity and richness of the soil within the limits special to each. The reason of this is of course the fact that the more favourable a soil is, the more vigorously will plants nourished in it assimilate; and the result is manifest by an increasing fulness of crown, which completely changes the habit of the species in question. Thus *Terminalia tomentosa, Bombax malabaricum,* &c., present quite different aspects in Northern, Central and Southern India. Trees grow noticeably closer together on low river banks and on northerly slopes. The effect just indicated is irrespective of the fact that in good soil plants can feed within less space and, therefore, have a more restricted ramification of roots.

The remarks in the preceding paragraphs should be read as an appendix to what has been said under Condition IV in the first two cases.

The shape of the crown also exercises a considerable influence on the struggle for existence. Sal, with its long narrow crown, is able to push up through any small gap it may find in the leaf-canopy above it. The long tapering crown of the deodar adds very considerably to its shade-enduring capacity. Shade-enduring trees will at once spread out a branch here and a branch there into any interstices they find. Of two species growing side by side and possessing similarly shaped crowns, but one of which tolerates shade better than the other, the second will ultimately disappear; whereas a third species, although much less shade-enduring than the second, but with a differently shaped crown, may be able to occupy a permanent place in the leaf-canopy.

Lastly, the relative ability of trees to push up through cover has to be considered. Facility for so doing, added to the faculty of persisting under cover, gives a tree, possessing it, an irresistible superiority over its neighbours. The manner in which young deodar makes its way up through the dense crowns of overhanging oaks and rhododendrons is an excellent instance in point. There are certain, by their original nature, shade-avoiding trees which,

thanks to this facility, assume the character of true shade-endurers and are then able to force themselves not only into, but through, the leaf-canopy above. Such species are either comparatively very rapid growers, or, from being in leaf and putting forth new shoots while their companions are entirely out of leaf, are able to spread out, both laterally and upwards, in spite of being overtopped or pressed up against by the crowns of these latter. The most remarkable instance of the first case is that already cited of the *Dendrocalamus strictus* and other bamboos generally, which, although extremely partial to light, will shoot up through the loftiest and deepest cover. Again, the strong leader of the teak will, provided it has not far to go to reach direct sunlight, pierce through the thickest tangled mass of foliage overhead. The second case is best illustrated by the *Hardwickia binata*, young plants of which gradually insinuate themselves through the crowns of the trees immediately above them, especially of khair and, of course, of *Boswellia*. Indeed the finest saplings are often those which have grown up in this manner through khair (see Condition XVI *infra*.)

V. RELATIVE MASS AND SPREAD OF THE ROOTS (INCLUDING THE RHIZOME).—In the heading here a new term has been introduced, *viz.*, "relative mass of the roots." In the two preceding cases, the species being one and the same in any single instance considered, although the *spread* of the roots of the various plants might differ, still the relative *mass* or *density* of the root system would be the same for all the plants and would be that peculiar to the single species to which they belonged. It is evident that the relative degree of closeness of the roots of a species must influence very considerably its behaviour in the struggle for existence. Thus some species develop a close matted mass of roots and rootlets, which strangle the roots of associated species growing with them. Others again also possess abundant spreading underground stems, which are much more invasive than mere roots. Thus the roots and rhizomes of species of *Carex*, *Andropogon*, &c., form a felt-like mass, often several feet thick, which strangle out all other growth. Once bamboo has taken possession of the soil, few individuals of other species can force their own roots through the dense tangled mass of its fibrils and root-hairs; and, conversely, when the soil and locality are both suited to the growth of bamboos, no individuals of other species which keep their roots within the same depth can coexist with them, only such trees as can spread out their

roots below the layer of the soil monopolised by the bamboos having a chance of gaining a permanent footing in the crop. Hence the frequent inability of teak, *Terminalia tomentosa*, and other species possessing more or less horizontally spreading roots to cope with bamboos, which cannot, however, keep out sal and other trees with deep-seated roots.

This last example introduces us to, and also illustrates, another point, *viz.*, the relative depth to which the roots of the various associated species can penetrate—a circumstance that has a most important bearing on the distribution of some of our most valuable species. To cite further instances, teak, the *Terminalias*, &c., as we know, spread out their roots within only six feet and often less of the surface, so that in shallow soils resting directly on a dry subsoil, they yield the place to *Boswellia*, *Anogeissus*, khair, *Prosopis spicigera*, &c. The *Prosopis spicigera* has been known to force its main roots down to 60 feet and more below the surface of the soil, and is, accordingly, able to flourish in the dry plains of the Punjab, whither hardly any of its companions of moister regions can follow it. Again the sal is one of the few trees that can grow on the waterless boulder deposit at the foot of the Himalayas, the roots of that species being able to penetrate down to a depth of 60 feet and even more; and this fact accounts for its generally forming much purer forests there than inside the hills. Many of the trees of the dry tracts of India, which bring out their leaves in the height of the hot weather, like the *Bassia latifolia*, *Buchanania latifolia*, &c., have been known to send down their dense network of fibrous rootlets 20 feet below the surface to tap the stratum of permanent moisture.

Confining ourselves to the consideration of young seedlings alone it may be laid down as a general rule that the longer the taproot developed by the yearlings of a given species is, the better are they able, other things being equal, to resist both frost and drought, and, therefore, the more likely is that species to predominate over its associates. Instances in point are sal, *Hardwickia*, &c. The long taproot of the *Terminalia tomentosa* yearling enables it to survive severe and prolonged drought, without, however, affecting the natural sensitiveness of that species to frost. We know that the deeper situated any layer of the soil is, the larger will be the quantity of moisture in it and the less exposed will it be to excessive fluctuations of temperature due to subaerial variations. Hence the deeper a taproot goes down, the more likely is it to

find sufficient moisture, and the higher will be the temperature of the moisture which it pumps up into the plant portion above during frosty weather—the one circumstance being a protection to the plant against drought, the other against frost-bite. And not only this, but since during frost the water contained in a certain thickness of the soil (which thickness will of course vary with the severity of the frost and the character of the soil) freezes and expands, and causes the soil to swell up with itself several inches, seedlings with a short taproot, after rising with the soil as this latter expands, must inevitably be left ejected when, on thaw occurring, the now soft and muddy soil settles down again. On the other hand, seedlings with a long and strong taproot would be generally safe against such a catastrophe, unless the taproot were torn asunder by the uprising of the superficial layers of the soil.

The behaviour of individuals of one and the same species in respect of each other, as their root apparatus goes on expanding with the progressive growth of the crop, is of course identical with what was described in the First Case, except in so far as it is modified by the action of other species present in the crop. This action has now been explained and will be still better understood after a perusal of the remarks made under this head in the Second Case. It is only after bringing together all the various circumstances detailed to a common focus that we can adequately appreciate the importance of the rôle played in the struggle for existence by a difference of root systems. That rôle is not inferior to the part appertaining to a difference of crown development and of requirements as to light and protection. No single species can utilise all the space in the soil any more than it can utilise all the space in the leaf-canopy above; and just as two species of different habits can grow up together side by side, whereas two having a similar habit cannot, so within a given area the soil may afford spreading room for a larger number of individuals of mixed species possessing different root-systems than of individuals belonging to species possessing a similar root-system. Hence the inability of individuals of any species to live under an open or even fairly dense canopy of another species is not necessarily an indication of their not being able to stand the existing amount of shade, for it may be entirely due to there not being room enough in the soil for them owing to both species possessing a similar spread and disposition of roots. See also footnote on page 29.

VI. Age of crop.—This condition is one of very great

moment in deciding the struggle for existence, since advancing age affects directly the action of most of the other conditions. How it does so, has been fully indicated in the separate discussion of each of those conditions, so that to consider the various points over again here would involve needless repetition of a very large portion of the present section. The student is also referred to the discussion of this condition in the First Case for the extent to which advancing age may change the relative fitness of individuals of one and the same species.

VII. RELATIVE LONGEVITY.—This factor has a most importance influence on the struggle for existence. That influence is so great that of itself it enables a species, placed at a disadvantage with regard to its companions in most other respects, to prevail in the end. The best instance of this is offered by the teak, which, in spite of every kind of ill-treatment, and of an ungrateful soil and climate, is able to form extensive copses on the dry barren hills of the Sathpuras and Southern Vindhyas. In the same way, the sal, although gregarious and fast-growing species like the *Tetrantheras*, bamboos, &c. may gain the upper hand of it at first, still lives long enough to see these disappear and leave it in complete possession of the ground. Indeed the greater longevity of the more valuable species seems to be a special dispensation of nature, otherwise useless or inferior kinds, like the *Cochlospermum Gossypium*, *Kydia calycina*, *Helicteres Isora*, *Mallotus philippinensis*, *Zizyphus*, *Mimosa rubicaulis*, *Indigoferas*, *Adhatoda Vasica*, *Blumea*, *Buddleia*, *&c.*, would simply choke up and drive out all better growth. See also remarks under condition VII of First Case.

VIII. RELATIVE RAPIDITY OF GROWTH.—The influence of this cause will be different according as this relative rapidity obtains during the first years of the life of a tree or at a later age. Other circumstances being equal, it is evident that species which grow up quickly during their early years will prevail over others which are of slower growth at that age; and we know that stool-shoots and suckers tend rapidly to smother out any seedlings that may come up simultaneously with them. In the habitat of the teak, bamboos everywhere, *Butea frondosa* in Central India, and some other species, complete at least half their growth before that valuable tree only begins to push upwards, the consequence being that, unless this last has a real start, it is more or less completely driven out. In most sal forests, besides the bamboo, it is the

Tetrantheras that push up rapidly and cover the ground while the sal is only just establishing itself. Among the companions of deodar, the *Pinus excelsa* shoots rapidly away soon after it germinates, and leaves that tree far behind in the race. It is thanks mainly to the wonderful rapidity with which teak stool-shoots grow up, that that species is so easily able to hold its own in the coppice forests of the Sathpuras and the Western Ghats. On the other hand, when growth becomes rapid only after the plants have attained a certain age, its vigour in the case of the larger species, provided of course that individuals possessing sufficient potential latent energy have survived up to that age, is always so great that nothing can withstand it. It is thus that when teak has survived up to this stage, it overcomes most obstacles to its growth; and so with sal, deodar, *Pinus longifolia*, *Hardwickia binata*, &c.

It is evident that relative greater rapidty of upward extension is of greater importance in the struggle for existence than similar rapidity of lateral extension; but lateral extension of the crown also means lateral extension of the roots, and hence it is not difficult to conceive a case of an individual of an extremely shade-enduring species, which is in its phase of active lateral development, easily maintaining its ground against, and even overcoming, a rapidly elongating individual of a shade-avoiding species. When a plant or species enjoys at the same time more rapid extension upwards and sideways, the species so favoured of course possesses an unquestionable advantage over all others similarly endowed in other respects. Observe the case of coppice shoots as against seedlings.

Deciduous trees standing in the midst of evergreen neighbours can survive on the sole condition that from the earliest years they grow more rapidly, not only upwards but also laterally, than their companions.

Regarding the rate of growth in height of our various species in mixed forest, we have no trustworthy information. And, indeed, in a continent like India, we are bound to obtain very different figures for one and the same species according to the locality and the region in which it may grow in each case. When such information is forthcoming, it will be very useful to construct comparative diagrams of the relative rapidity of growth of different species standing together in the same forest.

The varying rapidity of growth of each species would be delineated by a curve with its generating rectangular co-ordinates, the abscissa representing the age, and the ordinate the height of the average tree at that age. Figure 1 is such a comparative diagram for two trees, A and B; the curves are traced by means of the respective heights attained at 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 years of age. The diagram shows at a glance that up to the age of 49 years B grows faster than A; at

50 it is overtaken by the latter, which then gets away from it. The rapidity of growth of A is slow for the first ten years, then becomes rapid up to seventy years, after which it decreases gradually, and becomes almost stationary. B, on the other hand, grows up rapidly at once, until it reaches the age of 50 years, and then makes little head afterwards. In the diagram $\frac{1}{30}$ inch on the axis of X, or the horizontal line, represents one year, and similarly $\frac{1}{60}$ inch on the axis of Y, or, which comes to the same thing, on the perpendicular line, represents one foot.

Similar diagrams may be constructed to represent relative rapidity of lateral extension.

IX. RELATIVE MAXIMUM HEIGHT ATTAINABLE.—This condition finally decides what trees, out of those that survive up to a certain stage of growth, shall form the crop, or, if there are species present that are shade-bearing enough to constitute a permanent undergrowth, its upper story. Of the companions of sal there are only the *Terminalias*, some *Albizzias*, *Adina cordifolia*, *Pinus longifolia*, some *Eugenias*, and half a dozen other species which attain the same height as that noble tree, and which, therefore, compete with it for a place in the lofty leaf-canopy of the full-grown forest. In most of the forests of Central India (including Northern Bombay), teak is a small tree, and is hence, unless other conditions are prohibitory, easily beaten by its taller companions. Deodar is, as a rule, the tallest tree in the forests where it grows, whence its gregariousness in those places, whenever other circumstances, such as soil, moisture, &c., are favorable. Again, *Mesua ferrea* is, with the exception of *Altingia excelsa*, the tallest tree in the large areas which it covers almost by itself in Assam. The teak in Burma, and the *Artocarpus Chaplasha* in Assam, although unfavorably circumstanced in many other respects to struggle for existence with their companions, are able to hold a permanent place in their midst. In evergreen forests trees of deciduous species tower above all the other growth. The great advantage possessed by trees that can attain a greater height than their immediate neighbours is, that they are able to resist any amount of lateral pressure by always being free to develop in at least one, *viz.* the upward, direction. When such trees are also shade-enduring, they enjoy a double force of resistance, which makes them invincible, as, for instance, deodar in mixed deodar and oak forest.

X. RELATIVE SUITABILITY OF CLIMATE.—This is perhaps one of the most important conditions in the struggle for existence, for in almost every case it determines the habitat of the various species, and also the vigour of their growth. Many factors go to make up what is called climate, and they may best be considered separately :—

(*a*) *Heat and frost.*—The influence of these factors is due chiefly to extremes, being very little or scarcely appreciable within limited ranges of temperature. We will illustrate this statement with reference to teak. An examination of the subjoined table will show that teak can flourish and attain its finest dimensions with an absolute annual range in the open of as much as 134° Fah., provided the minimum does not fall below freezing point. As the minimum diminishes and the maximum in the hot weather rises, thereby increasing the absolute annual range of temperature, teak thrives less well, until it disappears altogether with an absolute range of 150° and upwards, with the minimum out in the open going down 7° and more below freezing point. The lowest minimum temperature under the open sky is almost the same at Seoni, Khandwa, Allahabad and Agra ; but on the other hand, frost is more frequent at the two latter places, and the evenings, night and mornings are generally many degrees colder—in other words the absence of a sufficiency of heat is more prolonged and, therefore, all the more sensible in its effects. For this last reason also although frosts are severer in Seoni and Khandwa, teak thrives better there than in Jhansi. Until the lowest limit of temperature is reached, a falling minimum manifests itself by a more languishing vegetation ; when that limit is passed, to languishing vegetation is added incapability of ripening seed.

Stations.	Minima.*		Maxima.				Absolute annual range in open	Remarks.
			in open		in shade			
	in open	in shade	hot weather	rains	hot weather	rains		
Thayetmyo	39	48	167	166	108	102	128	Teak flourishes.
Moulmein	43	55	169	164	98	90	126	" "
Karwar	54	56	161	159	93	89	107	" "
Mangalore	48	63	164	160	95	87	116	" "
Sironcha	34	46	168	160	116	95	134	" "
Raipur	33	41	176	165	114	98	143	
Seoni	25	40	173	161	111	94	148	Teak of only moderate size.
Khandwa	27	40	173	161	112	95	146	
Jhansi	33	44	181	163	114	98	148	Only scrubby teak
Neemuch	22	38	180	170	113	95	158	Just outside teak region
Allahabad	25	40	175	165	115	97	150	More than 100 miles beyond northern limit of teak.
Agra	24	40	180	176	116	106	156	

* These figures have been obtained at observatories standing in the midst of inhabited buildings and necessarily situated on moderately high ground. The minima temperatures out in forests and large grassy expanses are obviously several degrees lower a fact that must be borne in mind when reading the text.

A similar table to the above constructed for sal will show that that species lives between even wider limits of temperature than teak, or, to speak more explicitly, can stand a lower degree of cold and endure as much heat, provided it does not come in blasts, which, occurring, as they must necessarily do, at a season when sal puts forth its new tender shoots, are fatal to its existence. The *Terminalia tomentosa* cannot resist frost as well as teak but, as long as the temperature is above frost, it can stand more continuous cold, and is thus able to extend several degrees further north right up to the outer ridge of the Himalayas. In Sindh, the *chaors* and *kachas* along the lower course of the Indus are covered principally with babul, whereas higher up the river frosts become very severe and tamarisk gets the upper hand. In the Changa Manga plantation frost has killed out the babul and left sissu complete master of the ground.

But temperature does not only merely fix the limits within which a species can live, but also influences the proportionate distribution of the various species forming a mixed crop; for, while they can all live under the conditions of temperature obtaining in the locality, some of the species will resist the extreme limits better than others, some again will put forth greater activity than the rest during the prevalence of the predominating temperatures, and so on.

Absolutely speaking the effects of frost will be severer—

(1) in level than in hilly country, since, the elevation being one and the same, there will be more unchecked and, therefore, rapid radiation in the former case;

(2) on southerly and easterly than on northerly and westerly slopes, since on the former the sun shines as soon as it is above the horizon and hence causes rapid thaw;

(3) at the bottom of valleys than on the overhanging slopes, on which the air is in more constant movement and the young shoots of the trees are smaller and less sappy and more quiescent;

(4) in confined places where the air is still than in breezy or windy localities;

(5) in places exposed to chilly winds than where such winds cannot enter;

(6) in a mild climate with a long season of vegetation such as we have everywhere in India outside the very high mountain ranges than in a severe climate, since in the former the young shoots will always be more herbaceous and watery and will be less

likely to be in a quiescent state, and the frosts will occur chiefly at night, after and immediately before the action of a hot and, therefore, also forcing sun;

(7) in a dry than a moist atmosphere, since there will be less impediment there to radiation;

(8) in a moist than in a dry soil, the same result taking place here as in (6);

(9) in a sandy than in a clayey soil, since sand radiates more rapidly than clay;

(10) on a grass-covered surface than where the soil is bare, since the numerous small surfaces presented by the leaves and stalks of the grass aggregate together a much larger radiating surface than the naked superficies of the ground;

(11) at the surface of the earth than at any height above it: meteorological observations taken at the Forest School and in the Dehra Dun forests show a difference of sometimes as much as 5° Fah. between thermometers placed at 5 and 60 feet respectively above the ground.

(12) in a shallow soil or one difficult to penetrate for roots than in one in which the roots can go down easily.

As regards the relative effects of frost on the various species composing a crop, they will be directly proportionate—(i) to the expanse of the leaves and the roughness of the buds, leaves, and internodes; (ii) to the thinness of the leaves; (iii) to the quantity of water in the cell sap as compared with solid substances; (iv) to the looseness of texture of the active tissues; (v) to suddenness of thaw; (vi) to the thinness and late formation of the outer covering of dead bark (the *rhytidome*); (vi) to shallowness of rooting; and (viii) to the quantity of watery vapour in the atmosphere. We may hence deduce the following corollaries, granting always that other circumstances are equal:—(*a*) the more active the vegetative processes during the season of frosts, the more sensitive the tree; (*b*) the greater the number of dormant buds, the hardier the species; and (*c*) the more generous the growth of a young plant, the slighter its power of resistance.

Besides influencing the development of individuals of the various species, temperature also affects their ability to bear flowers and fruit (see Condition XII, *a* and *b*).

(b) Damp and drought.—Here also only extremes act. For instance, teak seems to thrive best under a mean annual rainfall of

from 50 to 120 inches, but does not disappear till the fall decreases to about 24 inches. Even the range of rainfall for sal extends roughly over 80 inches, *viz.*, from 40 to 120.

In the dry climate of Rajputana the *Anogeissus pendula* easily gains the ascendancy over all other species. The jand (*Prosopis spicigera*) finds no rival or compeer in the dry rakhs of the Punjab.

Under damp must be included, besides rainfall, also relative humidity. The sal will acquire its finest dimensions in the hot steamy valleys of the Lower Himalayas, but refuse to grow in Chanda and other places where the temperature during the hot weather is scarcely higher, but where nightly dews are neither heavy nor occur during any considerable part of the dry season.

This statement is supported and further illustrated by the following table which gives the figures of the mean relative humidity at the several places mentioned in it during the months of March—June, when sal is putting forth and developing its new shoots and is most in need of moisture. The table also explains how, owing to an excess of moisture, sal is unable to extend itself as far east as Sibsagar and Silchar, and that, therefore, it can have too much as well as too little atmospheric humidity.

STATIONS	MARCH	APRIL	MAY	JUNE	REMARKS
Gorakhpur	52	42	56	68	Within Sub-Himalayan belt.
Darbhanga	54	51	66	77	,, ,, ,,
Dhubri	?	69	81	87	,, ,, ,,
Hazaribagh	36	32	43	66	Within Central Indian area.
Sambalpur	53	46	51	67	,, ,, ,,
Sibsagar	79	81	82	83	Too wet for sal.
Silchar	73	76	81	85	,, ,,
Roorkee	51	35	36	52	Just outside sal area—too dry, hot winds.
Raipur	39	36	36	63	Some distance outside—too dry.
Chanda	41	34	34	60	,, ,, ,,

Doubtlessly the natural spread of sissu south of its range is limited by the drier atmosphere of the adjoining region. *Prosopis spicigera*, *Capparis aphylla*, and many other plants of Rajputana and the Panjab plains require less atmospheric humidity than most other Indian species. *Trewia nudiflora* is confined only to tracts visited by moist sea-breezes or to the vicinity of the Himalayas from the Jumna eastwards, where the air is always comparatively moist. The very high relative humidity of the inner ranges of the Himalayas enables evergreen species to prevail there, notwithstanding the low rainfall they receive.

The abundance and continuousness of rain at the beginning of the rainy season exercises a very strong influence on the germination of the seeds of the various species. The seeds of some species

have to go through a protracted process before they become perfect plants. A sudden break in the rains, and a few hours of strong sunshine before the process is complete, might kill the majority of such germinating seeds. This happened over several square miles in the Khandwa Reserve in Nimar in the Central Provinces, in 1879, in the case of the *Hardwickia binata.* Seeds of other species again, such as the *Terminalias*, teak, &c., require a large quantity of moisture to germinate, and hence their inability to extend into very dry districts, where otherwise circumstances are favourable for their growth and fructification. Moreover, if the monsoon rainfall is at first short, and the seeds of such species can consequently germinate only in the latter half of the season, the young herbaceous plants must fall easy victims to the hot sun of October and November and the frosts of December and January.

Lastly, it may generally be said that those species, the seedlings of which develop a strong, long taproot, will withstand more severe and continued drought and thus survive, while others, less favoured in this respect, will disappear or be left in the minority.

Besides influencing the growth and soundness of individuals of the various species, the amount of atmospheric moisture affects also the abundance and frequency with which they flower and seed (see Condition XII, *a* and *b*).

(*c*) *Light, its intensity and duration.*—Here also it is the action of extremes that exercises any appreciable influence on the struggle for existence, excessively bright light having the effect of over-transpiration and insufficient brightness the result of insufficient assimilation, the upper and lower limits of excess being different for different species and the difference being generally very much more marked in the case of the latter limit. Some species cannot make any vigorous growth except under exposure to direct sunlight. These form the majority of our Indian species, and include teak, sal, &c.; but amongst them there are many which can persist, and even push on gradually, with little illumination, like *Hardwickia binata, Anogeissus*, &c., which can survive long suppression, and sal, most of our climbers, &c., which can also slowly strengthen themselves and work their way up, except the cover be very thick. Other species, like the *Quercus incana*, silver fir, many laurels, &c., will flourish and attain their finest dimensions even in more or less diffused light. The figs require a great deal of direct sunshine, and hence their arboreal habit.

Going out of India to Northern Europe we have the Scots' pine and birch delighting in almost perpetual sunshine during half the year, and able to survive almost endless night during the other half. As rather more than one-half of India is situated within the Tropics, and of the rest the greater portion consists of level ground fully exposed to the sun, and within a few degrees of the Northern Tropic, the climatic influence of light on the struggle for existence, except so much of it as was considered under Condition IV, is of comparatively secondary importance save for those few species, such as the *Pinus excelsa*, deodar, and some other Himalayan trees, which require good illumination, but cannot stand heat, both of which conditions are satisfied by the altitude at which they grow. But this is anticipating subhead (*e*) below. The discussion under Condition IV should be carefully read in connection with the preceding observations.

Besides influencing the development of individuals of the various species composing a forest crop, the greater or less intensity of the light acting on their crowns, according to their different degrees of isolation, also affects the frequency and abundance with which they flower and seed (see Condition XII, *a* and *b*).

(*d*) *Aspect.*—Change of aspect may introduce changes in all or any one or more of the following conditions affecting the growth of plants:—diurnal and seasonal oscillations of temperature, quantity and distribution of rain and dew, atmospheric humidity, intensity and duration of sunlight, action of winds, and quantity, richness and humidity of the soil. This being so, it is evident that in hilly and mountainous country the influence of aspect is very great and often of itself determines the distribution of species. In Southern Nimar, in the isolated block of hills known as the Sambar Deo range, on the left bank of the Tapti, the southern slopes bear *Hardwickia binata*, while the northern ones, being cooler and moister, are covered chiefly with a dense teak copse, a rare *Hardwickia* being visible here and there. In the outer North-West Himalayas, *Pinus longifolia* generally affects the warm southern and eastern aspects, while oaks with rhododendron clothe the northerly and westerly slopes. Nevertheless lower down, where sal and that pine meet, the latter, which is a tree of a colder climate, is represented chiefly on northerly and westerly slopes, the sal occupying the warmer aspects. Going up higher, into the region of deodar, *Pinus excelsa* is the ruling tree on warm southerly aspects; silver fir, spruce, *Quercus dilatata*, and *semecarpifo-*

lia, with maples, birch, *Celtis australis*, &c., predominate on cold northerly and westerly aspects; while deodar prevails in the middle ground.

In dry districts in Central and Southern India, the *Dendrocalamus strictus* affects the cooler northerly and westerly slopes; whereas in Bengal and along the foot of the Himalayas generally, where the climate is damp, it is found chiefly on the warm southerly faces of the hills. In other words, the aspect affected by a species may vary with the amount of atmospheric humidity of the localities in which it grows.

In regions in which frost occurs, hardy species are favoured by southerly and easterly aspects, on which the rapidity of thaw due to the sudden action of the early morning sun increases the dangerous after-effects of frosts, especially of night frosts, which always occur when most of our forest species are in active vegetation. We may thus find a species predominant on those aspects in one locality and slightly or not at all represented on the same aspects in another, simply because frost is seldom or not at all known in the one place and prevails in the other.

Aspect is always intimately connected with altitude, as we have already seen above and will find further explained and illustrated under the next subhead.

(*e*) *Altitude.*—The main effect of altitude is to reduce temperature and also to increase thereby the humidity of the soil and the atmosphere; but it has, besides, the important effect of prolonging the duration of sunlight, and, by reason of the clearness and rarity of the atmosphere due to it, of increasing the effect of the sun's rays. Hence it often reverses the effect of aspect, as we have already seen under the preceding subhead in the instance of *Pinus longifolia*. Another example is to be found also in the outer Himalayas in Kumaon, where oak forest, although chiefly confined to cool northerly and westerly aspects, takes complete possession of southern slopes from the line where *Pinus longifolia* stops. In the Siwaliks and on the outermost ridge of the Himalayas sal generally prefers northerly aspects owing to the lower elevation; but when that species approaches its highest limit, it is confined to southerly slopes. At the upper limit of tree vegetation the effect of aspect is entirely nullified by altitude.

(*f*) *Winds*—In the case of winds we have to note their direction, velocity and prevalence, and their relative temperature and

humidity as compared with the temperature and humidity of the air at the place under consideration. Hence the influence of winds on the struggle for existence between the plants of a forest crop is tenfold. Firstly, by their violence they can uproot, injure the roots of, break off, mutilate, distort, or stunt the trees; secondly, they can alter the relative humidity of the locality according as they are drier or moister than the latter; thirdly, they can reduce or raise the temperature according as they previously pass over a colder or hotter region, this effect being heightened in proportion to their velocity; fourthly, provided their temperature is above the dew-point or that of freezing, they delay and diminish the deposition of dews and mitigate the severity of frost or even prevent frost altogether; fifthly, they may blow away the covering of dead leaves and other vegetable detritus; sixthly, they always accelerate evaporation; seventhly, provided they are not too cold, they also accelerate transpiration; eighthly, by constantly renewing the air, they promote assimilation; ninthly, by causing the leaves and branches to sway to and fro, they accelerate the movement of sap; and tenthly and lastly, they disseminate seed to distances proportionate to the lightness and transportability of the seed. And all these various effects may be slight or aggravated according as the wind is intermittent and local, or constant and of long duration.

Of two trees of the same species, that one will resist better the force of the wind which possesses the broader crown, since the extent of the roots is proportional to the size and vigour of the crown; and of two trees of different species possessing the same spread of crown, that one will resist better which has the more open crown. Again, of two species, one may be deep-rooted, while the other has its roots more or less superficial and is consequently less able to resist violent movements of the atmosphere. Thus sal is comparatively rarely blown down by the wind. So also where storms and gales are frequent, as on ridges, spurs, peaks, in narrow gorges, or on the sea coast, the strong-rooted individuals will be the ultimate survivors, and species with weak superficial roots will have to retreat to sheltered localities. After a deep and strong root-system, strength and elasticity of the wood is the most important quality a species can possess as a safeguard against violent winds. A species that is leafless when a strong wind is blowing is of course less likely to be injured than one in leaf; hence in exposed windy situations deciduous trees, as a rule, thrive better than evergreens. Rain accompanying increases very considerably the violence of a wind.

A species that is in leaf, or brings out its leaves, when periodical hot or chilly winds blow, will generally suffer more than those that are leafless at the time. Thus the hot winds limit the expansion to the south and west of the Sub-Himalayan sal belt. But species with leaves or other transpiring organs of firm texture, or covered with a thick and waxy epidermis, such as *Prosopis spicigera*, *Euphorbias*, the tamarisks, *Capparis aphylla*, &c., are of course able to offer a more or less successful resistance.

XI. GRADIENT.—One of the principal effects of gradient, when there is no impeding cause, is to drain off the moisture of the soil. Trees like sissu, the tamarisks, &c., require a great deal of continually moving water in the soil, and they can hence grow only where the ground slopes very moderately but the soil transmits water freely. Other species, like sal, require a less quantity of water and a less perfect, though still free, drainage; hence their affecting only steep or rolling hill sides, except, when, as in the Bhabar, the soil itself or at least the subsoil lets water pass through it as through a sieve. A third class, like teak, requires still less moisture in the soil, but does not object to a less free drainage, whence its ability to grow both on hill sides and on gently sloping ground with less or more binding soil. A fourth class, like the *Pinus longifolia*, requires even less moisture in the soil than the preceding but the most perfect drainage, and will hence, where the soil and subsoil are not freely permeable, confine itself to slopes with a gradient of at least 30°. A fifth class, like some *Euphorbias*, objects altogether to any very appreciable quantity of moisture in the soil, and will on that account grow only on scarps, where the rainfall is at all plentiful; and so on.

But with species growing on hill sides it is not simply a question of drainage. They must also possess roots adapted to hold on firmly to steep slopes; and hence of two trees, similar in every other respect, that one will possess a decided advantage which has the stronger and more firmly-seated roots. Moreover, species with horizontally spreading main roots will usually prosper better on slopes than on level ground, since there half their main roots will be able to penetrate into and hook themselves on to the hill side, whereas on level ground every such root will be superficial, *e.g.*, oaks, *Cupressus torulosa*, *&c.*

Exaggerated gradients increase the possibility of erosion and landslips, and species with a close and strong network of roots, being able to hold together the soil and rock, can thereby not only

anchor themselves more firmly than others less well endowed, but also nourish themselves better.

Gradient exercises also three other very important effects on the growth of the individual plants of a crop. In the first place on it depends the largeness of the angle of incidence of the solar rays and hence their heating and illuminating power, which is obviously more effective the more vertically they strike the plane of the ground. In the next place, gradient regulates the intensity of the light reaching overtopped plants through openings in the leaf-canopy above, since, the height of the trees forming the canopy being constant, the steeper the slope is, the nearer will the open sky necessarily be, and *vice versa*, the distance in any case being the product of the difference between the heights of the overtopped plants and of the canopy-forming trees multiplied by the cosine of the angle of slope. And in the third and last place, since the actual superficies of a slope is greater than the area of its horizontal projection, being that area multiplied by the secant of the angle of slope, the steeper the slope is, the depth, moisture, &c. of the soil still continuing the same, the larger will be the number of crowns capable of crowding together on the slope. Every tree, not having another of greater height immediately below it, will have its crown free on that side although it may be overtopped by the tree immediately higher up.

Lastly, gradient affects the distribution of the seeds of the various species. On a steep slope heavy and round seed will roll away, few being caught to reproduce the species. It is for this reason that the oaks grow less abundantly on steep than on moderate slopes.

XII. SEEDING.—This condition may be considered under six subheads, as follow :—

(*a*) *Its relative abundance.*—It is evident that, other circumstances being the same, a species that produces abundant crops of seed will, even if at first in the minority, secure an easy predominance. Instances of profusely seeding species are bamboos, and the grasses generally (*facile principes*), sal, sissu, deodar, *Quercus incana* and *semecarpifolia*, *Pinus longifolia*, teak, &c. In Mauritius *Tetrantheras*, *Albizzia Lebbek*, and other trees, introduced from India but seeding more abundantly than the indigenous trees, now occupy by themselves entire hill sides.

Considering any one species by itself we may say that the abundance of its seeding at any time will depend—

(i) On its age: the older a tree is, provided it is not in full decline, the larger will its crown be and hence the more fruit will it bear;

(ii) On the soil; the better the soil, the larger will be the crown of the tree and the more nourishment will it be able to draw up and elaborate for the formation and ripening of fruit;

(iii) On the climate of the locality: the more favourable the climate, the more vigorous and better developed will be the tree and the larger the quantity of superfluous food it can elaborate to store up in the seed; hence greater fruitfulness, the nearer it is to the heart of its habitat, especially if the species in question is accommodating in respect of climate;

(iv) On its full enjoyment of light: for without it the crown will be spare and incomplete, and most, if not all, the food it can elaborate will be used up for its own development. Vegetative vigour is, under normal conditions, always greater than sexual vigour, and hence, unless there is more food than what the development of shoots and leaves can utilise, sexual vigour will remain dormant or hardly manifest itself.

(v) On the characteristics of the current season: the temperature may be too low or too high; too much moisture being present in the soil just before the flowers are due, foliage may be developed at the expense of the flowers; the development of foliage buds being checked by a dry season, the superfluous reserve matter stored up from the preceding season may be used up in producing an abundance of flowers; and so on;

(vi) On the absence or otherwise, during the process of fructification, of accidents due to parasites, insects, fires, &c.

Of two species possessing equal longevity, that which seeds at an earlier age is often also the one that seeds more abundantly. For instance, teak, babul, *Anogeissus*, sissu, sal, &c., are amongst those of our species, which seed in the greatest profusion.

Some species require a larger sum total of heat than others in order to flower, and hence also to seed. Hence comparatively poor seed crops where a species occurs in a climate appreciably colder than that of its main habitat. This is most conspicuously illustrated by those species which are accommodating in respect of variations of climate, as for instance, teak, *Pinus longifolia*, &c.

It has already been pointed out that without a completely developed crown no species will seed abundantly. From this it obviously follows that the more shade-enduring a species is, the

less insolation, and, therefore, the less isolation does it require. Hence in a more or less full canopy, the more shade-enduring species, *cœteris paribus*, have a decided advantage over the rest in perpetuating themselves in the crop. Another result follows from the same fact. If trees of various species have grown up for a long time in a leaf-canopy too close to allow any to flower, and if the canopy is then suddenly opened out, those trees that can soonest form a complete crown will naturally first produce abundant seed, and the species they belong to must, therefore, tend to predominate over the rest. This power of recovery is not necessarily proportionate to shade-enduring capacity, and deodar, a remarkably shade-enduring tree, is known to take at least 12 years after being released from a close leaf-canopy to bear any considerable quantity of seed.

In the case of some species, as, for instance, *Hardwickia binata*, sissu, khair, &c., once they have put forth blossoms, very hot or cold weather following scarcely affects the subsequent development and ripening of the fruit. With others, on the contrary, such as sal, teak, deodar, &c., unfavourable weather, if it does not result in the destruction of the entire crop of flowers, nevertheless allows only a relatively small proportion of it to live and become mature fruit. Similarly the flowers and fruit of some species are more liable to be attacked by insects and fungi than those of others.

As a general rule, the relative abundance of seeding of the various species will be directly proportionate to the smallness of the seeds they produce; while as regards species producing more or less the same size of seed, those will generally bear more plentifully which are of more vigorous growth. Hence in any given soil or locality, the relative profuseness with which the several species composing a crop will seed, will depend on the relative suitability of the soil or locality for them. Similarly, in any crop those species will, *cœteris paribus*, fructify most abundantly, which are nearest to the heart of their habitat.

(b) Its relative frequency.—While with some species, as sal sissu, khair, *Anogeissus latifolia*, *Anogeissus pendula*, *Terminalia tomentosa*, &c. generally, and teak and *Pinus longifolia* within the main range of their habitat, seed-bearing trees in numbers are seldom, if ever, wanting in any year, with others, on the contrary, like the *Hardwickia binata*, most bamboos, &c., not a single tree will be found even in flower for several years together. Between

these two extremes there are obviously various intermediate degrees, comprising the greater number of our arborescent species. Greater frequency of seeding is obviously a marked advantage in the struggle for existence. Nevertheless, as we have already seen in the case of bamboos, great profuseness can more than make up for long intermittence, even where the associated species seed abundantly every year. It is obviously when the species concerned is also shade-enduring, and able to push up through cover, that frequent seeding alone without combined abundance, can give it an easy predominance; but when abundance and frequency of seeding are combined in one and the same species, as in the case of our herbaceous grasses, the species so favoured enjoy an enormous advantage.

The annual or intermittent seeding of the various forest species is, of course, due to their nature. For instance, the bamboos will under no circumstances throw up flowering shoots every year in a general manner. But even with trees which produce inflorescence buds annually, the ravages of frost, drought, fire, insects, &c., will sometimes cause seed to fail. Such failure must be traced to the interval between the appearance of the buds and their final change into ripe fruit; and the liability to failure from those causes will of course be proportionate to the length of this interval. Thus between the appearance of the flower bud and the maturation of the cone of the deodar more than a whole year elapses, with the consequence, in the severe climate affected by that species, that seed fails on an average in one year out of every three; whereas the corresponding interval in the case of the companion firs, which ripen their cones at shorter intervals, does not exceed nine months, and the bursting forth of their buds, and the whole process of fructification, occurs between April and November of the same year, *i.e.*, during the mildest months. Similarly, teak near its northern limit in India, although, thanks to the genial temperature during the rainy season, it flowers abundantly every year, sometimes fails to form fruit owing to the heavy frosts of December and January. And so with *Terminalia tomentosa*, &c. On the other hand, the entire activity of the inflorescence bud of sal is accomplished between March and the following June, so that, unless fires are so exceptionally severe as to scorch up every green thing in the crowns of the trees, or insects are exceptionally numerous and destructive, a certain quantity of seed must be produced every year.

Some species, like the *Hardwickia binata* for instance, produce flower buds generally, or only, in very dry years. Drought has also,

no doubt, some influence on the flowering of bamboos, which frequently coincides with, or immediately follows, years of scarcity. And, indeed, drought may generally be said to favour the production of flower-buds by weakening and diminishing the foliage the trees.

Frequency of seeding is also dependent on the degree of density of the leaf-canopy, some trees, as already stated under (*a*), requiring a smaller measure of isolation than others to produce flowers and fruit. For instance, it is a matter of common experience in Assam to find isolated individuals of *Mesua ferrea* loaded with fruit, while the seed collector wastes his pains in canopied masses of that species. The same is strikingly the case with deodar in the N. W. Himalayas.

And generally it may be said that whatever favours profuseness, also favours frequency of seeding.

(*c*) *Size and transportability of the seed.*—Large and heavy seeds, like acorns, will drop almost vertically on the ground, while the minute seeds of *Stephegyne, Adina, Pieris,* &c. will be blown away to considerable distances by the slightest breeze. But large and heavy seeds also may, thanks to foliaceous or comaceous appendages, such as are found in teak, sal, *Pterocarpus Marsupium, Terminalia tomentosa,* &c., be wafted away some distance from the parent tree by wind. When small or light seeds are armed with such appendages, they may be blown away for miles; *e. g.* seeds of many herbaceous grasses, of *Asclepiadeæ, Apocyneæ,* elms, &c. For instance, hundreds of thousands of young *Stereospermum suaveolens* will be found covering several square miles of ground, which do not contain a single fertile tree of that species.

Then again water may transport seed over long distances, as is strikingly illustrated by tamarisk, babul, sissu, khair, cocoanuts, &c. Another interesting example of this may be quoted. The nearest limit of the true region of *Anogeissus pendula* from the northern boundary of British Nimar is not less than 150 miles along the course of the Narbada and its tributaries; nevertheless the banks of that river, where it runs through the dry Vindhyan barrier north of Punasa, is covered in places with a dense low growth of that species, the outcome of seed brought down the river and arrested there. But it is not only the action of large volumes of water that is important; in a less striking manner, but on a considerably more extensive scale, the slight depth of water that

rushes over the surface of the ground when heavy rain is falling, suffices to displace seeds over vast areas, so that while in some places, with numerous seed-bearers overhead, all the seeds shed may be washed away, other places containing no seed-bearing trees of a given species may be plentifully sown with seed of that species.

But the transport of seed is facilitated not only by its lightness or its appendages, or by water, but also by its edibility. Thus the heavy seed of the *Diospyros Melanoxylon* is disseminated far and wide by bears, jackals, men, &c., who are greedily fond of its sweet pulpy fruit. So with various species of *Zizyphus*, with *Gmelina arborea*, *Myrica sapida*, *Schleichera trijuga*, *Buchanania latifolia*, the sandalwood tree, wild pear, *Terminalia belerica*, babul, *Tetrantheras*, *Michelia Champaca*, &c. In the Changa Manga Plantation an abundant undergrowth of mulberry has come up under the original pure sissu crop. Birds are active distributors of the seeds of the various species of *Ficus* and *Loranthaceæ*, depositing them on their future hosts in places favourable for their reception. But animals, by swallowing seeds, not only disseminate them, but also accelerate their germination, the secretions of their stomachs and intestines producing a favourable reaction on the reserve matter. Thus in babul groves in the Deccan the penning of goats for a few days under them, when the fruit is ripe, results in a dense carpet of seedlings, which otherwise are not produced in any great numbers.

The force of gravity also acts directly in the dissemination of seed on inclined ground, the heaviest and roundest seeds obviously rolling away furthest. Very steep slopes can be sufficiently sown, by a species producing such seed, only under specially favourable circumstances, as where the ground is covered with a close growth of undershrubs, and so on.

(*d*) *Season of fall of seed.*—In forests where fires are an annual occurrence, seeds shed at any time before that plague has passed through, are bound to be almost wholly destroyed, only a few escaping which fall on bare ground clear of combustible substances, or find their way into cracks, or under stones, &c., or which belong to species, like the teak, *Terminalia belerica* and *Chebula*, &c., for instance, the seeds of which can stand a high temperature without being killed. Species like the sal, eng, tun, *Tetranthera monopetala*, &c., the greater proportion of the seeds of which falls at the beginning of the rains, when the season for fires

is over and all nature is green and damp, possess a very marked advantage over their associates. The gregariousness of *Quercus dilatata* and *semecarpifolia* is to a great extent to be explained by the fact that their acorns ripen and fall during the rainy season.

And, in a general manner, it may be said that the longer the interval between the fall of the seed and the ensuing rainy season is, the greater will be the number of risks to which it will be exposed from fires, insects, squirrels, rats, &c., and hence the less chance will there be of finding a large proportion of it fit to germinate when that season arrives.

(*e*) *Relative vitality of the seed.*—This condition has a most important influence on the reproduction of a species. Teak, although its seed is shed when jungle fires are about to commence, and has to lie for several months on the ground exposed to various causes of destruction before the first fall of rain, is still able to reproduce itself freely, thanks to the extraordinary vitality of its seed, which even a certain degree of scorching will not kill, and which remains perfectly sound after several years of exposure to alternate damp and drought in the forest. On the other hand, the seed of the *Terminalia tomentosa*, unless it finds moisture enough to germinate at the beginning of the very first rainy season, at once rots and dries up. Oily seeds soon go bad, as the oil is easily oxidised : *e. g.* seeds of deodar and most other conifers, of *Artocarpus*, *Bassia*, &c. Small seeds, like those of *Anogeissus*, *Stephegyne*, *Adina*, &c., are killed in numbers simply by the heat of the sun during the hot weather, and but for that circumstance, those species would easily overrun, as the two *Anogeissus* actually often do, the whole forest wherever they grow. As regards the *Anogeissus pendula*, however, water seems to exercise a strongly preservative effect on its seeds, which, as already mentioned above, are carried down by river more than 150 miles, to ultimately germinate where it is deposited. This peculiarity is also well illustrated by the production of new forests of sissu, khair, tamarisk, and babul. For the most remarkable instances of vitality, however, we must go to the grass family.

(*f*) *Relative facility of germination.*—This condition has a very marked effect on the reproduction of the various species composing a crop. Thus in sal forest, there is every year a more or less plentiful new crop of seedlings of that species produced, where-

as, save in exceptional years and places, yearlings of the allied species are either wanting or are entirely in the minority. This is due to the sal seed germinating as soon as it falls, and sometimes beginning to do so even before it is shed, while that of its companions, although many of them are annually fertile, germinate with much less facility. Similarly, in the N. W. Himalayas, the acorn of *Quercus semecarpifolia* frequently develops a long tap-root before it falls soon after ripening at the beginning of the rains. Teak, in spite of its profuse and generally annual seeding, nevertheless, as a rule, produces every year only a very small number of seedlings, owing not only to the early fall of its seeds, but, throughout India proper, chiefly to the excessive difficulty with which it germinates, having often, under the most favourable circumstances, to lie in the soil for upwards of two years. There are other species, the actual germinative process of which spreads over several days, so that when once that process has begun, if a sudden prolonged break in the rains should occur, and the soil dry up at the surface under a hot sun, it must be immediately arrested and the germ killed. Such species are *Terminalia tomentosa*, *Gmelina arborea*, &c. Again, the same class of seeds, for the very reason that their germination is protracted, are also often liable to rot from temporary excess of moisture and consequent inability to obtain the full quantum of oxygen necessary to render the reserve matter soluble. But the most striking instance of superior germinative facility giving an infinitely great advantage to species that possess it, is that of the grasses: whence the extreme difficulty of restocking open treeless land.

(*g*) *Relative age of fertility.*—The earlier a species comes into bearing, the greater the chance it has of not only perpetuating itself in the crop, but also of increasing its own proportionate distribution in the next generation. With the sum total of other conditions against it, it can still at least successfully resist complete banishment. Most shrubs and small trees enjoy this advantage, without which the majority of them must inevitably be driven out in time.

Considering any one species by itself, the less vigorous individuals are earlier fruitful, so that those growing further away from the heart of their habitat or under less favourable conditions of soil or climate frequently come into bearing earlier, a dispensation of nature that enables many species to enjoy a wider distribution than they would otherwise possess. It will be observed that amongst

introduced species, annuals and biennials generally manifest the strongest tendency to become subspontaneous.

XIII. RELATIVE POWER OF HEALING OVER WOUNDS.—Wounds may, although exposing living tissue, not penetrate as far as the wood, or they may go as far as the wood without removing its cambium layer, or they may remove the entire cambium layer.

In the first alternative, a protective layer of cork is formed immediately under the exposed surface, thanks to the still existing, though limited power of cell-division possessed by the green parenchyma of the bark; and this may happen at once, independently of the season of the year, provided of course the temperature is not excessively hot or excessively cold. Now it is obvious that in proportion to the thickness and vigour of this parenchyma will be the rapidity with which the protective covering will form. As instances of rapid formation we may cite sal, *Terminalia tomentosa*, *Boswellia thurifera*, *Pinus longifolia*, &c.,

In the second alternative, the exposed wood cambium may be covered up by new protective tissue before it can dry up, or it may dry up before this tissue has time to form. When the latter happens, the result is the same as in the third alternative to be treated lower down. But when the cambium continues moist long enough, the parallelopiped-shaped cells composing it are in a few days transformed by active division into cubical cells forming a covering tissue, which becomes green under exposure to light. Not unfrequently the entire cambium layer, the medullary rays excepted, may dry up, when the same covering of healing tissue may be formed exclusively by those rays. However it be, the new tissue soon differentiates itself into wood, cambium and bast, with a corky layer outside of all. Now it is evident that the chances of the cambium remaining moist sufficiently long for the formation of this protective covering will depend not only on the condition of the weather (rain, a saturated atmosphere, &c.), but also on the secretion of gum or resin, as in *Acacia arabica*, *A. Catechu*, *Boswellia thurifera*, *Pinus longifolia*, &c., or a continuous and abundant outflow of sap, as when a tree is coming into new leaf (sal, mahua, &c., in the hot weather, and so on).

In the third alternative the wound can be covered only by means of the gradual closing in of the edges by the abnormally active formation of new, constantly overlapping tissue there. Now we know that this kind of healing is facilitated to such an extent by the thinness and vitality of the new bark formed along the en-

croaching edges and its comparative freedom from dead bark on the outside, that the largest wounds may become completely closed over in a short time in favoured species, and even relaively small wounds may remain open for a long series of years in less fortunate species. Thus is accounted for the great ease with which such wounds heal up in the *Boswellia thurifera*, in teak, &c.

XIV. RELATIVE FACILITY OF REPLACING LOST OR DAMAGED AERIAL ORGANS.—This will depend on several circumstances, the principal of which are—

(a) *Ability to develop adventitious buds.*—At all ages such buds may, with different degrees of facility and abundance according to the different species producing them, form on the section where the organ has broken off or is bruised. In seedlings and saplings of most of our broad-leaved species, the presence of collum buds is the surest guarantee we can have of their being able to renew in the happiest manner broken or injured parts. As a rule, those species produce most collum buds, which, as young seedlings, develop a stout and fleshy tap root compared with the small and, for their age, generally insignificant-sized aerial portion; such are, sal, teak, *Sterculia*, *Dalbergia latifolia* and *Sissoo*, &c. It is also a noteworthy fact that amongst species which produce such buds, those individuals are most prolific in them which, within certain limits, are the least vigorous, the otherwise arrested energy of young plants being evidently diverted to the root-collum.

(b) *Tendency to form accessory buds.*—Some species, such as the sal, *Terminalia tomentosa*, *Eugenia Jambolana*, *Mallotus philippinensis*, hawthorn, hornbeam, ash, &c., regularly develop such buds, and indeed some of them, as the *Mallotus philippinensis*, hawthorn, &c., owe all or the majority of their branches and foliage to them. Since accessory buds, appearing, as they do, after the regular normal bud near which they are produced, are always less advanced than the latter, and as they seldom sprout unless those buds are already dead or injured, it is evident that species developing them possess a certain guarantee that there will always be a sufficient number of buds immediately under the broken off or injured part ready to sprout and replace it.

(c) *Possession of covered buds enclosed by scale leaves.*—As in each such bud there may be, according to the species concerned, from five or six to more than twenty five of these leaves, and as their internodes never develop when the rest of the bud elongates

and forms a branch, it is evident that, even when the bud has sprouted, there will always be at the base of the new branch, and practically on the stem bearing it, as many buds as there were scale leaves, each such bud being the regular axillary bud of the corresponding scale leaf. So that at each node of a stem there are always numerous buds ready to sprout on receiving sufficient provocation, such as the loss or injury of the whole or part of an important organ. The marvellous coppicing and pollarding power of the *Butea frondosa* is a very remarkable instance in point. The small abortive leaves on the outside of the buds of sal may also be considered scale leaves.

(d) *Presence and abundance of dormant or latent buds.*—Amongst conifers the *Pinus longifolia* and yew possess true dormant and even latent buds, but such buds are to be found only on wood under 10 years old, if we except seedlings of languishing growth of the pine, which retain them for perhaps double that period. In deodar and larch the abortive shoots, which constitute the bundle of needles and which can under favourable circumstances develop into shoots, can hardly be termed dormant buds, since they are after all true shoots; moreover, they do not persist for more than a comparatively limited number of years, and they can obviously, in the very nature of things, never become latent. Amongst our broad-leaved trees and shrubs there is none but in which a large proportion of the buds formed each year become dormant and even latent.

At first we will consider the difference in the number and vigour of the dormant buds only as regards the various individuals belonging to one and the same species. That will depend on—

(i) The origin of the plants.—Size for size, young plants from the seed will, under average conditions, generally possess more dormant buds than stool-shoots and suckers, and stool-shoots than suckers. The superiority of seedling plants is due not only to their greater age and the inferior vigour of their crown, implying the development into organs of a smaller proportion of the buds produced, but also to their better general health, their shorter and, therefore, more numerous internodes, and the greater thinness of the dead bark covering their stems. Plants on stools are better off than suckers principally because of the sudden arrest of vegetation that always follows when they have exhausted all the reserve food stored up in the parent stools, especially if they have come up in clumps, and of their more knotty development. With

advancing age, the advantage which individuals from the seed possess, increases, for, except under adverse conditions, they are always much more healthy and vigorous, produce more numerous twigs and small branches, and, therefore, also more buds, and are longer lived. The difference between stool-shoots and suckers is soon lost with age. Pollards, which are always very rich in dormant buds, have been excluded from consideration here, since they are really mutilated individuals, that is to say, individuals not growing under average conditions.

(ii) The age of the plants.—A plant that has just come up cannot, from the very nature of the case, possess dormant buds; but as it grows on, provided it belongs to a species capable of possessing such buds, a certain proportion of the buds produced during each growing season become dormant; and this proportion increases in geometrical progression, not only because of the rapidly expanding crown, but also of the multiplication by division of pre-existing dormant buds. Thus each successive year adds an increasing quota to the ever-swelling number of dormant buds in the tree or shrub. This goes on all through the phase of longitudinal growth, while the development of the crown is comparatively restricted, and even continues during the early part of the phase of lateral expansion. Then the rapid spreading out of the crown and the more vigorous circumferential growth of the stem and branches appropriate a constantly increasing proportion of the food elaborated, and thus, owing to failing nourishment, the ratio of increase of the dormant buds diminishes, until at last all increase ceases and ultimately a steady diminution, beginning at the base and top of the tree and progressing towards the middle, sets in from gradual inanition followed by death. But the lower portion of the crown or the upper half of the bole possesses dormant buds to the very last.

(iii) Repeated temporary arrests of vigour of crown.—Each time there is such arrest, there is a superfluity of elaborated sap, which then goes to feed the dormant buds. These buds thus receive a strong stimulus, which not only keeps alive those about to perish from want of nourishment, but also strengthens the rest and enables them to multiply very considerably. Some of them may even sprout and stimulate still further their immediate neighbours. The arrest of vigour of the crown must be sudden, otherwise, when it occurred, there would be hardly, if any, reserve store of food in the plant to reinvigorate existing dormant buds and produce new ones. Indeed these arrests, if frequent and sudden enough

within certain limits, may give such a preponderance to the dormant buds, that the entire surface of the woody cylinder of the tree or shrub in question may become a mass of warty excrescences formed by those buds, as is conspicuously exemplified by mutilated specimens of *Celtis Roxburghii*. In the same way a stem hardly a foot in diameter may throw up, when cut back, a clump of more than 100 shoots.

The arrested vigour of the crown here discussed may come about from one or more of the following causes :—

1. Drying up of the soil in the hot weather ;
2. Great heat or cold, including hot and chilly winds, and excessive insolation and frost ;
3. Conflagrations ;
4. Pollarding and every description of lopping and hacking ;
5. Breaking of a branch from any cause whatsoever ;
6. Depredations of insects and other animals ; and
7. Excessive light.

All these causes are more fruitful, numerous and effective in this country than in Europe. Thus to abundant rain and a bright and hot sun during the season of vegetation succeed cold and even frosty nights in the cold weather ; nay, in the cold weather itself, a high forcing temperature during the day is at once followed by a rapid fall of the thermometer at sundown ; and so on. Hence the very much greater vigour and number and longer life of dormant buds in Indian trees and shrubs.

(iv) Richness and suitability of the soil for the species in question.—It is evident that the more suitable the soil is, the larger will be the amount of food a given extent of leaf-surface can assimilate, and, therefore, the larger the quantity of nourishment available for the use of the dormant buds.

We have now to consider the difference in the number and vigour of the dormant buds in individuals belonging to different species. This will depend on—

(i) The number of buds, normal, accessory or belonging to scale-leaves, produced at or near the axil of each leaf, and the number of the collum buds.—The scale-leaf buds, being generally very rudimentary, can develop only on the condition of the excessive mutilation or weakening of the original shoots at the base of which they lie; *e. g.* the brushes of shoots sent up by young sal, when the leader has been killed by fire or frost, or by chilly nights following a hot steamy forcing day ; &c. As covered buds may each

comprise up to 25 or more scale leaves, and, therefore, *at least* as many buds in addition to the accessory or any other buds produced in contact with them, it is evident that a tree with covered buds, *cæteris paribus*, enjoys an immense advantage over another with naked buds. But sometimes the outer leaves of naked buds attain very little development when the buds sprout, and the internodes between them remain more or less abortive, in which case a naked bud partakes of the nature of a covered bud in respect of the number of undeveloped buds at or near the base of a shoot or in the axil of a regular foliage leaf.

As regards accessory buds, it may be said that a great many, if not the majority, of broad-leaved trees and shrubs in India produce them, although in most cases they are so rudimentary, that they cannot easily be detected and develop only under the action of some strongly inciting cause. But it is such rudimentary buds that are the most likely of all to remain dormant.

Lastly, although, as has been said under Definition 68, most of our broad-leaved trees and shrubs below the higher regions of the Himalayas produce collum buds, yet some species form more numerous and vigorous ones than others. Besides enabling the young seedling to renew itself as often it dies down, these buds form all or the majority of the shoots, which later on the plant can throw up if cut back flush with, or even inside, the ground.

(ii) Different degrees of development of contiguous buds.—If all the buds produced at any point were of one and the same strength, they would all sprout together, forming a brush of shoots. Hence it is essential that some should be so much more rudimentary than the rest that they remain undeveloped when these latter sprout. Scale-leaf buds are the most rudimentary of all, and species possessing them are always the most prolific in dormant buds. Next come accessory buds, especially if they are situated below the true normal bud. These inferior accessory buds are generally so concealed under the stipules or even the base of the petiole of the leaf, at the axil of which they are produced, as in *Eugenia Jambolana, Wendlandia exserta*, &c., that they are naturally hindered from developing save under a strongly exciting cause. Collum buds are, by their origin, well protected from the light, and the curling up of the tap and side roots draws them still further into the soil, especially if this is rich and loose; but the generally very adverse conditions under which forest seedlings in India grow up, force the developmental energy of the young plant into

them, and some of them do become dormant simply because of their concealed position inside the soil. Sometimes, as in teak in the scrub forests of Central India, they acquire so much absolute vigour, that they sprout and form fairly strong shoots round the base of even the living tree.

(iii) The shade-avoiding nature of the species.—The more light-demanding a species is, the stronger must be the exciting cause for a given bud to sprout, and, therefore, *cœteris paribus*, the greater the proportion of buds that tend to become or remain dormant.

(iv) Early formation of the secondary bark.—The sooner buds are covered over by the formation of the secondary bark and withdrawn from the influence of light, the greater the chance obviously of their continuing dormant and of their surviving injurious weather influences. Besides this, the soft bast, in which the herbaceous portion of the bud lies embedded, helps indirectly, and sometimes even directly, to nourish those buds.

(v) Deciduousness.—In evergreens most of the protoplasmic matter from the leaves about to fall pass into the younger contiguous leaves, which, being in full function, would moreover draw it towards themselves with very much greater force than any dormant buds that may be equally near. On the other hand, in deciduous trees and shrubs, a very large proportion of those substances is necessarily stored up in the woody portion during the absence of foliage, and the dormant buds, even those farthest from the crown, are consequently better nourished. Moreover deciduousness is after all a kind of sudden temporary arrest of vigour of the crown.

(vi) Rapidity of multiplication of existing dormant buds.—This will depend not only on the amount of nourishment which those buds receive, but also to a great extent on the arrangement of the leaves. The amount of nourishment is always regulated by the conditions treated under the preceding heads (iv) and (v), and by the extent of mutilation or weakening of the transpiring and assimilating organs and the suitability of the soil; and hence it follows that species may, provided other circumstances are favourable, possess more numerous and more vigorous dormant buds, the further away, within certain limits, they grow from the centre of their habitat. This also accounts for our Indian trees being able to coppice more abundantly and vigorously, and up to a more advanced age, than trees in Europe where the climate is more conducive to regular growth.

As regards the arrangement of the leaves, it is evident that in

species with opposite phyllotaxis the dormant buds will treble themselves at each division, and that the greater the tendency there is for the leaves to agglomerate themselves at the ends of shoots, or for the branches to become shortened (form *brachyblasts*), the larger will be the number of buds formed in a single season by each original dormant bud.

Up to this we have discussed the relative facility with which individuals and species *replace lost or damaged organs.* When a tree or shrub is cut back, or pollarded, or deprived of its lower branches in order to curtail as much as possible the development of its crown and roots, we have in the consequent production of the stool-shoots or new poll or new side-shoots, whichever they may be, special instances of the larger case just considered, the first being an extreme one. Facility for growing up again from the stool is more particularly dependent on the number, vigour and longevity of the dormant buds, especially of those originating from collum buds, and only to a slight extent on the production of adventitious buds. Pollarding and pruning constitute really only two definite kinds of mutilation, and, if effected on rational principles, they encourage in a marvellous manner the formation of numerous and vigorous dormant buds; but in pollarding, and, more particularly, in pruning, we rely in a very large measure also directly on the presence of accessory and scale-leaf buds, and, to a greater extent than in coppicing, on the formation of adventitious buds.

XV. RELATIVE FACILITY OF THROWING UP ROOT-SUCKERS.—The faculty of producing root-suckers is limited to a comparatively small number of trees, but in revenge those which possess it, have a permanent important advantage over their companions. We know that suckers originate from adventitious buds, and that such buds, although they may form anywhere on a young root, are produced more abundantly and with greatest certainty along the edges of wounds, and generally wherever the progress of the elaborated sap, coming down from the crown, is arrested and there is a release of pressure. Thus standing trees bearing all their organs throw up most suckers in shallow soils of uneven texture (unevenness caused by presence of stones, &c.), in which the roots develop unequally, being more vigorous at certain points than at others owing to better oxgyenation and less impediment to their expansion. Moreover the faculty of throwing up suckers is always increased by any kind of mutilation of the aerial

portion of the tree, being greater in proportion to the extent of the mutilation, *i. e.* to the diminution of other organs capable of carrying off the developmental energy of the tree. Sufficient aeration is an absolute necessity for the formation and subsequent development of adventitious buds on the roots, for the buds could not be produced and begin to sprout without the presence of oxygen, and, once they have begun to sprout, they must have a constant supply of carbonic acid. Hence in waterlogged soils trees reproduce themselves badly by means of suckers. This also explains why, in the irrigated plantation at Changa Manga, the sissu fails to grow up again satisfactorily when stubbed out.

In Central India, *Ougeinia dalbergioides* forms large masses of pure forest on land recently abandoned by cultivation, the husbandry operations having helped to multiply the number of suckers from the original plants. The same, although to a much less degree, may be said of the *Diospyros Melanoxylon* in the same forest region. One of the main causes of the predominance of *Boswellia thurifera* in the dry forests of Central India is the facility with which it throws up suckers. The gregariousness of sissu in Northern India is also in a great measure due to the same cause, as is also the invasive character of *Buchanania latifolia* in Northern and Central India, and of *Excœcaria sebifera* wherever it has been introduced.

It is evident that those trees and shrubs produce most suckers, which send out long lateral roots that run along close under the surface of the soil. The *Ougeinia dalbergioides* enjoys this peculiarity to a very remarkable extent, as may be observed from the long rope-like roots, which, from being unable to attain organic contact with the soil, even by means of secondary roots, creep along the surface of sheet-rock on hill sides. Such completely exposed roots, however, seldom produce suckers, as they become too hard and woody under the unimpeded action of the sun's heat rays, and, being free to develop equally on every side, vigour of growth is too uniformly distributed along their surface.

XVI. RELATIVE DURATION OF FOLIAGE, AND SEASON OF ITS FALL AND RENEWAL.—This condition influences to a very remarkable extent the distribution of many species in a crop. It is evident that, other circumstances being equal, the longer a species remains in leaf during the year, the better is it adapted to secure ultimate mastery over its companions. A tree in leaf is constantly assimilating new material for its growth, and either spreading

itself out in every direction, or preparing to do so, the result being that it is able to steal a march on its leafless neighbours, and this with conspicuously greater effect if the season for the renewal of its foliage occurs earlier. Thus, where the climate and soil are suited to evergreen species, these always predominate over their deciduous companions. In some parts of Burma evergreen species have invaded the confines of teak, and surrounded in their close embrace isolated trees of that species, which will now be the last of their race there. Again, the sal, which is all but an evergreen, is able to suppress most of its would-be rivals. Thus in the Raipur district of the Central Provinces it has encroached on the teak in many places. The *Anogeissus pendula* is leafless for only a short time in spring, and tolerates few companions of other species. On the other hand, the *Boswellia thurifera*, besides possessing an open crown, is leafless for from eight to nine months; so that, although for other and more potent reasons it does grow gregariously, it nevertheless allows other species not only to push up into the leaf-canopy on a level with itself, but also to occupy a permanent and often large place there. Such species are *Hardwickia binata*, *Anogeissus latifolia*, teak, khair, &c., which all retain their foliage for some months after the *Boswellia* has shed its own, and renew it from several weeks to several months earlier. Indeed, in many localities, the *Boswellia* may be looked upon only as a temporary natural crop to be replaced later on by more favoured species, to which it is now acting as a nurse, and which will drive it out, or at least predominate over it, when they no longer require its protection.

The number of flushes of new leaves that a species brings out during the year is also an important factor for consideration. Every new flush of leaves is accompanied with a sudden outburst of both lateral and upward extension, during which the tree is able to push up against and through obstacles, against which it may at other times be completely powerless. The *Hardwickia* produces at least two such flushes every year, and hence its ability to beat species much more shade-enduring than itself. Thus where it grows with khair, it is common to see young *Hardwickia* seedlings and saplings gradually making their way up through the close crowns of poles and trees of that species. The khair being leafless in April, when the *Hardwickia* brings out its first and strongest flush of leaves, the young plants are able to push up

then without any impediment. Then, when towards the end of the hot weather or at the beginning of the rains, the khair puts forth new foliage, they become overshadowed, but do not remain so long enough to suffer in health or vigour and yet long enough for the new shoots produced at the second flush to remain sufficiently herbaceous to form long internodes and thus help them to push on faster them they would othewise do.

We may also quote the example of sal and *Terminalia tomentosa.* The latter species is very much more shade-enduring and broader-crowned; nevertheless, when the two grow close together, the sal can go up straight and force its neighbour to contract its crown on its own side and extend it in other directions.

Lastly, where late frosts occur, trees that bring out new leaves early in the year will naturally suffer more than others whose foliage-buds begin to swell up, preliminary to bursting forth, only after the frosts are past. *Abies dumosa* suffers in this manner; and thus also is explained the impossibility of acclimatising deodar and the Indian silver fir in Northern Europe.

XVII. A CLIMBING HABIT.—Under condition III (*g*) we have explained how climbers, considered as an extraneous accident in a forest crop, kill or at least weaken trees, and thus *assist neighbouring trees* in gaining the victory in the struggle for existence. In this place, on the contrary, we are concerned with the struggle between the *climbing plants themselves,* considered as forming an integral portion of the forest crop and the trees on which they climb.

Plants with a climbing habit rise up into and spread over the crowns of their supports either (i) by means of adventitious roots, which enter the very smallest crevices in the bark, and attach themselves firmly thereto, *e.g.*, ivy, *Ficus scandens,* &c.; or (ii) by means of tendrils, which grasp by merely curling up round any sufficiently thin body with which they come into contact, *e.g.*, the whole genus *Vitis, Bauhinia Vahlii,* many rattans, &c.; or (iii) by means of tendrils which, when unable to meet a plant part sufficiently thin to be grasped by curling up round it, may nevertheless fix themselves to any, even moderately rough surface with the help of their free extremity, which at once swells up and flattens itself out, thereby growing into and completely filling up the minutest crevices and sinuosities, and becoming adherent thereto, after the manner of adventitious roots, *e.g.*, the vines; or (iv) by means of hooked spines, *e.g.*, many rattans, *Cap-*

paris horrida, &c.; or (v) by means by twining round the stems and branches of their supports, at first generally in a loose coil, and then with a tight grasp, *e.g. Millettia auriculata, Spatholobus Roxburghii, Bauhinia Vahlii, Butea superba*, the vines, *Celastrus senegalensis, Combretum decandrum* and a host of other climbers; or (vi) and lastly, by interlacing branches with, or simply resting up against or on the stems and branches of, their supports, *e.g., Dalbergia volubilis, Acacia pennata, Cudrania javanensis*, &c. From the few examples just given it will be observed that the same climber may employ more than one mode of ascension. Thus the vines twine as well as possess tendrils, which themselves can grasp both by curling up and by attaching themselves like adventitious aerial roots; *Bauhinia Vahlii* not only has tendrils, which after the disarticulation of the curled-up portion, are reduced to mere hooks, but also twines and scrambles up; the rattans twine and also possess tendrils, and moreover, to a certain extent, scramble up, in which mode of ascension they are assisted by their numerous prickles; the climbing figs twine as well as creep up by means of adventitious roots; and so on.

Whichever the mode of ascension followed, the result is always the invasion and overspreading of the crowns of the supports by the dense foliage of the climber. The least harm done is impeded growth, and a sickly condition of the support. Moreover, when the climber ascends by twining, the stems and branches of the supports get constricted, the increasing pressure on the bark, following the entire circumference of the stem, prevents the free vertical diffusion of the elaborated sap coming down from the leaves and other green parts; and finally, the channel for the passage of the crude sap from the roots becomes disproportionately smaller and smaller for the nourishment of the crowns, which become, in consequence, scraggy, sickly, and full of dead twigs and branches (the cause of future interior decomposition and attacks of insects and fungi), and, if the trees form a heartwood, there is ultimately no sapwood left in their trunks, and death from sheer inanition is the result.

As with all other plants, so with climbers, the immediate effect of light is to cause early and, as far as the species in question is concerned, complete lignification, and thus to check the enlargement of their tissues, which are indeed in most, if not in all, cases, naturally of looser and more herbaceous texture than those of erect woody plants; and hence most climbers exposed to full sunlight and

wanting a support become low erect bushes (*Millettia*, *Bauhinia*, *Zizyphus*, &c.), or at least assume only a straggling habit (*Spatholobus*, *Butea*, &c.). With defective illumination, stopping short of the minimum absolutely necessary for assimilation in each case, climbers will form long internodes, and extend themselves vigorously; and indeed the largest of them are found in dense evergreen forests. Taking the special case of twiners, we know that the nutating end of the stem has comparatively small leaves (in *Bauhinia* none at all) and long internodes, exactly as if they grew in weak light, and this character is no doubt the result of a habit still continued, although the inducing cause (*viz.*, deficient illumination) is absent. Moreover all climbers are shade-enduring, for without that quality they could not, as they actually do, make their way up through the very densest crowns, as well as develop an aggressive mass of leaves in the midst of the already abundant foliage of those crowns.

One more characteristic of many climbers, especially those which twine or scramble up, is that they grow very rapidly in length. Thus, for instance, *Bauhinia Vahlii* often attains a length of more than 50 feet in a single season, and throws up long shoots which are at once able to reach the crowns of shrubs and low trees. It is this property especially which enables such climbers to attack and overcome trees more shade-enduring than themselves (see p. 47, para. 1).

To sum up: Climbers, no matter how they ascend, are able, thanks to their being shade-enduring to a very remarkable degree and often capable of rapid elongation, to rise up into, invade, and overspread the crowns of neighbouring trees, no matter how dense. They thereby not only prevent these latter from extending themselves either upwards or laterally, but reduce the quantity of their foliage, kill, and prevent the development of, twigs and young branches, and induce premature decay and death. They are most destructive, if they are also twiners.

GENERAL REMARKS.

It will be apparent from the foregoing considerations that a mixed crop, which consists of trees of one and the same age, must, in most cases, become gradually either more or less pure, or differentiated into groups, each composed more or less exclusively of a single species. This species may be the one most suited to the given soil and locality; but it is not necessarily that one, and

provided that both those main factors of production are sufficiently favourable for its prosperous growth, it is essentially that species which is the most tenacious and exclusive of the crop. Its tenacity will depend on its innate vigour up to at least the age of fertility, on the resistance it offers to the causes of injury described under Condition III, on its shade-enduring capacity, on its greater longevity, on the depth to which its roots penetrate, on the greater facility with which it grows up again from the stool and throws up root-suckers, and on its ability to ripen, and reproduce itself from, seed. Its exclusiveness will be due to the greater suitability of the soil, subsoil and locality for its growth, to the greater density and more favourable shape of its crown, to its capability of pushing up into and through the crowns of other species, to its greater rapidity of growth (especially during its youth), to its superior stature, to the greater facility with which it shoots up again from the stool and throws up root-suckers, to the longer duration of its foliage and the season at which this is shed or renewed, to the number of flushes of leaves it brings out in a single growing season, to the invasive spread of its roots or underground stems, to the readiness with which it replaces a broken or injured leader, to the easy dissemination and germination and great vitality of its seed, and to the season at which this ripens and is shed. A species may be tenacious without being exclusive, as *Boswellia thurifera*, *Prosopis spicigera*, *Acacia Catechu*, *Hardwickia binata*, teak in most cases, *Pinus longifolia*, &c.; or it may be exclusive without being tenacious, as, for instance, sissu at Changa Manga, where without watering and special care it would entirely disappear; or it may be both tenacious and exclusive, like sal, *Anogeissus pendula*, many bambus, *Ougeinia dalbergioides*, *Quercus semecarpifolia* and *incana*, deodar, silver fir, sissu in its proper station, &c. As long as the soil and climate do not keep out other species, mere tenacity alone will not suffice to enable a species to predominate; it must be exclusive as well.

The conclusion to be drawn is obvious. If our object is to raise mixed crops, we may be certain that, as a general rule, we cannot secure a favourable and permanent mixture by having them of uniform age throughout.

For further observations connected with this subject the student is referred to the "General Remarks" under the Fourth Case.

Examples of the Third Case.

Instances of this Case are furnished by many mixed khair and

sissu forests, mixed tamarisk, *Populus euphratica*, and babul forests, copses in which no standards are left, &c. Artificia y raised forests coming under this head are extremely rare in India if they exist at all.

SECTION IV.

FOURTH CASE.—Mixed crop composed of individuals of all ages.

We have already seen that in a mixed crop consisting of trees of one and the same age, the consideration of the circumstances which decide the struggle for existence is extremely complicated, and that none of them can be examined apart without having to take into account the effects of some other or others. Under this head we have one more cause of complication, *viz.*, the existence of various ages. That circumstance influences more or less the working of nearly all the rest, and the best plan to follow would, therefore, seem to be to repeat here, in their due order, all the headings of the three preceding Cases, and consider under each what qualifying effect it produces. Hence in what follows it must be understood that, in the absence of any qualification, whatever has been said under those Cases holds absolutely true also in the present one.

I. INNATE VIGOUR.—The comparative innate vigour of a plant will obviously depend to a very great extent on its age. The natural sal seedling makes little head in the forest until its gradually increasing vigour enables it, when established, to make a sudden start when it is several years old; whereas its companions, the *Tetrantheras, Kydia calycina, Miliusa velutina, Eugenia operculata*, &c., push up rapidly soon after they germinate. In the same way the two or three-year-old *Pinus excelsa* will grow up as vigorously as a deodar several years older. In many forests of the Central Provinces teak will remain only about a foot or two high until it is often more than twelve years old, when it will at once make a rapid start upwards. And so too at a later age the vigour of one species will diminish earlier than that of another. In other and more general terms, although the innate vigour of a tree will depend very much on its age, nevertheless greater age will not always be an advantage in the struggle for existence.

II. GREATER SUITABILILY OF SOIL AND SUBSOIL.—It has already been said (page 25) that for one and the same species the unsuitability of a soil or subsoil increases with advancing age.

Hence in the case of a soil that is well suited to only one of two species growing on it, the other may have a start of several years, and yet be ultimately overtaken and outstripped by the former.

III.—DEATH, DISEASE, UNHEALTHY STATE, OR RETARDATION OF GROWTH BROUGHT ON BY CAUSES EXTRANEOUS TO THE FOREST *viz.*—

(*a.*) *Attacks of insects and other animals.*—The presence of old and decaying trees will cause a multiplication of insects, which may also injure to a less or greater extent the younger trees, and also individuals of other species. But on the other hand, in a properly treated forest, there is no reason why trees should be preserved until they have begun to decay and serve as nests and centres for the spread of injurious insects. The removal of those trees in time is always possible, since neighbouring younger individuals of one or more species are already present, ready to take their place, a circumstance, the absence of which in crops of one uniform age throughout, not only aggravates the attacks of insects where a certain age has been reached, since the proportion of unsound trees is then very much greater, but also necessarily fails to provide the means of easily combating them, except at the risk of opening out the forest too much and letting in injurious climatic influences and concomitant evils. Moreover in mixed crops of different-aged individuals the surrounding young, and, therefore, presumably healthy, growth serves, if not as a complete check, at least as a temporary break, to the spread of the pest. As regards the ravages of deer, cattle and other herbivorous quadrupeds, it is evident that individuals small enough to be within their reach are, in most cases, very effectually protected, if they stand in the midst of a taller growth of other species not touched by those animals.

(*b*) *Attacks of parasitic and epiphytic plants.*—There is nothing new to add here after what has been said under the same head under the Third Case.

(*c*) *Damage caused by climatic influences.*—Against frost, drought, and sunstroke the shelter of older trees of hardy species is often indispensable, and is always useful, for the permanence of other species that are delicate in their youth. In the torrid valleys and plains of Rajputana, nearly every nim tree springs up out of an Euphorbia bush ; and, similarly in the Dehra Dun, nearly every tea bush has one or more tun plants growing up through

it, so that a tea garden left to itself would soon degenerate into a pure tun grove. In the Changa Manga Plantation mulberry has possessed itself of the ground under the original sissu. In creating a new forest where there has been none recently, it is often found necessary to raise at first a crop of a hardy species, under the shelter of which more valuable, but less hardy, species are afterwards introduced. Hence difference of ages in a mixed crop is a great help to delicate species in the struggle for existence and is in most cases an obligatory condition for its presence in sufficient numbers, and often even for its permanence.

(d) Conflagrations.—A crop consisting of trees of various species and different ages forms, as a rule, a denser growth and leaf-canopy than any other, and is hence exposed to less risk from fire. So that here also a difference of ages is a great help to weak species, which would otherwise suffer more severely from fire. Indeed it is not difficult to imagine the case of a species, well endowed in every respect to struggle with its neighbours except in the sole matter of resistance to the injurious effects of fire, being kept down in, and even almost banished from, a crop subject to annual or frequent conflagrations, yet easily predominating over every other species in another crop that is completely protected from fire.

(e) Floods.—Here again the closer growth consequent on a difference of ages, by offering a more or less effective obstacle to, and thus diminishing in a very large measure, the violence of a flood, increases the chances of the survival of the weaker species. Even as respects submergence, in a crop of different ages every species is likely to be represented by individuals old and, therefore, tall enough to stand above the level of all but the heaviest floods. As regards the superabundance of water in the soil due to floods, if on the one hand, the closer growth implies a larger total transpiring surface, on the other hand, the denser leaf-canopy restricts insolation and the free entry of winds under the crowns, both of them powerful factors in the evaporation of soil-moisture. Lastly, the presence at all times of large individuals of species suffering no injury from saline substances in the soil, may, owing to the abstraction from the soil of a large proportion of such substances by those trees, enable other species to exist, and even to flourish, although the flood waters may contain enough of the substances in question to kill or at least badly hurt them, if they were growing pure.

(f) *Action of man.*—The presence of trees of different ages and different species, affording, as it does, a wider field for selection, is a guarantee that the timber-dealer will, because they do not suit his purpose for one reason or another, or because others suit it better, spare many individuals of each species, which will then survive long enough to become the parents of a younger generation. The most casual visit paid to forests containing teak, sal or deodar, the most valuable of our trees, will prove this, even in such a backward country as India is. When fuel is not wanted, all unsound trees of the better species and every individual of other species are spared, and these perpetuate their kind; and when whatever marketable produce the crop can yield is taken out, seedlings and saplings, which sustain less injury from felling, export and conversion operations than larger individuals, are at least left, unless the ultimate object be to make a clearing for cultivation, building, &c.; and even in this last case, it is generally much more difficult to clear effectively when there is a difference of ages than when all the individuals are of one and the same age.

The preceding remarks suppose the absence of every idea of forest conservancy. When the crop is worked in accordance with correct principles, every facility is afforded by a difference of ages for the preservation and culture of the better species and individuals, even if these be weaker in most respects than their rivals. And even when the forester does not possess a sufficient knowledge of his profession, he is likely to make fewer mistakes in a crop of various aged individuals.

(g) *Climbers.*—There is no addition to make to what has been said under the preceding cases, except that special attention may be drawn to the fact that the presence of different species and various ages necessarily means the existence of several stories of growth and, therefore, affords at all times every facility for the ascension of climbers, although, on the other hand, the closer mass of roots in the soil and of foliage in the leaf-canopy tends to keep them back during the first stage of their development.

IV. DENSITY OF THE LEAF-CANOPY; RELATIVE DENSITY AND SHAPE OF CROWN, AND RELATIVE CAPABILITY OF PERSISTING UNDER, OR PUSHING UP THROUGH, COVER.—The shape, height, depth, width and density of the crowns of trees and shrubs differ not only from species to species, but also from individual to individual belonging to one and the same species according to their respective ages.

Thus it is in a mixed crop composed of individuals of all ages that we have the greatest variety in these several respects. Two important results follow thence. In the first place, young individuals of one species or another will generally be present and be able at once to occupy any space occurring from whatsoever cause in the leaf-canopy, and every species will be thus given a fair chance of maintaining itself permanently in the crop; and, in the second place, a crop of mixed species and ages will usually be the densest of all.

V. RELATIVE QUANTITY AND SPREAD OF THE ROOTS (INCLUDING THE RHIZOME).—Until decline sets in, the spread, closeness and absorptive power of the roots of trees and shrubs increase with age. Consequently young individuals, and especially seedlings and saplings, are not only unable to push their roots about in the soil, but may often be completely starved out, if they are growing in the midst of, or under, a close growth of larger individuals possessing the same root system. In the present case, with a variety of species present, there is always a chance of the larger individuals having a different spread of roots and making a different demand on the soil, and thus enabling the younger stems not only to persist, but even to gradually establish themselves until an opening in the leaf-canopy and more room in the soil, constantly afforded by the disappearance from time to time of some of its old or otherwise perishing neighbours or the contraction of the roots and crowns of those on the decline, gives them an opportunity of shooting up. In other words, in a mixed forest composed of individuals of various ages, reproduction by seed, and to a less extent by coppice shoots, is singularly facilitated.

VI. INDIVIDUAL AGES.—Only one additional point under this head need be noticed here. The presence of a variety of ages gives weak species a better chance of resisting banishment from the crop, since some at least of its representatives, of a sufficient age to have acquired the greatest tenacity of which it is capable, is almost sure to have for neighbours either very young or very aged individuals of the stronger associated species, against which they could then of course hold their own.

VII. RELATIVE LONGEVITY.—Young individuals of some otherwise favourably circumstanced species may outlive their older immediate neighbours of other kinds possessing greater longevity,

and thus enable that species, in spite of even marked inferiority in this respect, to maintain itself permanently in the crop.

VIII. RELATIVE RAPIDITY OF GROWTH.—As said before, some species have their period of rapid growth early in life ; others later. Young individuals of the one class may, therefore, outstrip older trees of the other class and thus prevail in the end. But, on the other hand, these latter may be old enough to have entered upon their phase of rapid growth, and then they may, in spite of disadvantages in other respects, maintain the start they originally had. As the relative ages of the trees of the several component species of a crop usually vary from point to point, the one result may follow as often as the other, and thus the permanence, although it may be in very different proportions, of all the species in question is assured.

IX. RELATIVE MAXIMUM HEIGHT ATTAINABLE.—Age can obviously exercise no influence on this Condition.

X. RELATIVE SUITABILITY OF CLIMATE.—As under this Condition we have considered only the influence climate exercises on the general growth of one species, taken in its entirety, as compared with the similar influence it exercises on another, the question of age affects the remarks already made under this head under the Third Case only to the extent that the constant presence of large and, therefore, protection-affording individuals of species better adapted to the climate mitigates its excessiveness for associated species that are less at home, thereby enabling such species to thrive better than they could otherwise do.

XI. GRADIENT.—One of the effects of gradient being rapid and effective drainage, it follows that on slopes with a naturally dry soil young plants, to whatever species they belong, will be safer against drought when growing with larger individuals, especially if all or most of these possess a strong root-system, a circumstance of more likely occurence if there are several species present. Under the same circumstances the young plants are also better protected against erosion and damage by snow. Moreover the neighbourhood of large trees of various species, all of which would seldom be out of leaf simultaneously, would necessarily prevent excessive insolation on slopes receiving the sun's rays more or less perpendicularly, and also mitigate the severe after-effetcs of frost on steep easterly and southerly slopes.

XII. SEEDING.—Under the Third Case this Condition was considered under seven main subheads. Here we can obviously make additional remarks only under the first, second, fourth, fifth and seventh subheads, *viz.* the relative abundance and frequency of seeding, the season of fall and the relative vitality of the seed and the relative age of fertility.

(a) Relative abundance.—A tree becomes fertile long before it has attained its full size and spread of crown, and it remains so up to the moment of its natural death. With the majority of our species, the quantity of seed produced increases with the age of the tree until decline sets in, when it gradually diminishes as the crown contracts and becomes more and more spare from year to year. From this age onwards the fruitfulness of the tree generally diminishes rapidly. With individuals of different ages and species mixed indiscriminately in the crop, at every point will be found a tree of one species or another in more or less full bearing, so that every species will be represented by some individuals at least which can perpetuate it in the crop, and a permanent mixture of the majority, if not all, of them will be thereby assured.

(*b*) *Relative frequency.*—In the case of those species which seed in a general manner only after an interval of two or more years, it is not uncommon to find some individuals here and there seeding within that interval. Thus *Dendrocalamus strictus* flowers sporadically every year. Again, in Nimar, in the Central Provinces, *Hardwickia binata* flowered gregariously in 1873 not at all in 1874 and 1875, sporadically in 1876, and again gregariously in 1877. As a rule, the individuals that flower thus sporadically are among those which possess the least vital energy (this seems especially to be the case with *Dendrocalamus strictus*). Such individuals are generally the older ones. Hence it is an advantage for a species, that seeds only at long intervals, to be represented by at least a few old trees, which extraneous circumstances do not prevent from flowering and bearing fruit.

(*c*) *Season of fall of seed.*—Individuals of one and the same species flower and ripen and shed their seed, at short intervals one before or after another, never all together. This want of simultaneousness is, in addition to other causes, due also to a difference of ages, which thus increases the chances of a more or less considerable number of seeds of every species present falling at a favourable moment and thereby successfully germinating each time the species in question seeds.

(*d*) *Relative vitality of the seed.*—As a rule old or very young trees produce seed, the vitality of which is more easily destroyed than that of seeds furnished by vigorous trees of middle age. Hence a species may be weak in numbers, and yet be comparatively strong enough, from being represented chiefly by individuals of middle age, to be able to perpetuate itself.

(*e*) *Relative age of fertility.*—In the case under consideration, the presence of various-aged individuals prevent the more precocious species from invariably enjoying an unqualified advantage over the rest. Indeed it may happen that the former, from being generally represented by very much younger individuals, may stand at a disadvantage.

XIII. RELATIVE POWER OF HEALING OVER WOUNDS.—This will depend to no inconsiderable extent on individual ages, irrespective of species. Thus advantage in point of age may tell very much in favour of an otherwise less fortunately placed species.

XIV. RELATIVE FACILITY OF REPLACING LOST OR DAMAGED AERIAL ORGANS.—Advancing age will obviously diminish the general faculty of reproducing lost or injured parts. Hence an absolutely strong species in this as well as in other respects may, from being simply represented by old individuals, ultimately find itself at a disadvantage.

The most important point under this condition is the power of growing up again from the stool. All species possessing it lose it after a certain age varying with the species in question. It is, at first, while the diameter is still very limited, only slight, then increases rapidly, next becomes stationary for a few years, and, lastly, gradually diminishes. Hence, where clearings or fellings on an extensive scale have been made, the new crop may consist of species that are not necessarily the most fitted for the struggle for existence; those most fitted may have been represented in the original crop chiefly by old trees past their coppicing age, while of the rest there may have been also numerous sufficiently young individuals to throw up coppice shoots.

XV. RELATIVE FACILITY OF THROWING UP ROOT-SUCKERS.—The faculty of throwing up root-suckers is at first *nil*, then increases with the spread of the roots until the tree begins to decline, when the principal roots themselves gradually weaken and die off at their extremities, while the entire root system contracts

and the number of the smaller roots and root-fibres, on which the sucker-producing adventitious buds originate, diminishes very considerably.

XVI. RELATIVE DURATION OF FOLIAGE, AND SEASON OF ITS FALL AND RENEWAL.—It is an almost general rule that within one and the same species the younger individuals not only retain their foliage longest, but also bring out the seasonal or annual flush earlier and frequently shed them later. And that, if by any chance the foliage of the season is destroyed, the young individuals (not always, however, the very youngest, since they are poor in dormant buds) renew it earliest.

XVII. A CLIMBING HABIT.—It is only after the first few years, when the young plant is thoroughly established, that a climber begins to nutate or throw up shoots which develop tendrils or adventitious roots, or which are long enough to scramble up other trees or shrubs. Once this period is reached, age has no further effect as far as the climbing habit is concerned.

XVIII. AN ARBOREAL HABIT.—This is a new Condition, since an arboreal habit necessarily implies the existence of different ages. Plants possessed of this habit are either (i) parasitic, like *Cuscuta*, fungi, &c. ; or (ii) only partially parasitic, like *Viscum*, *Loranthus*, &c. ; or (iii) purely epiphytic, like some figs, *Araliaceæ*, &c.

Parasites and epiphytes generally have already been taken account of under Condition III (*b*) as injurious "causes extraneous to the forest." In this place we have to deal with only such of them as form an integral portion of the forest, and have to struggle against other plants for a place in it. Under this category come only some of the species falling under class (iii).

In the case of trees with an arboreal habit, which, like the figs, become terrestrial as soon as their roots reach the ground, the epiphyte is bound to prevail over its temporary host, the trunk of which is gradually strangled by, and, in the majority of instances englobed within, the mass of long stem-like amalgamating roots given out by the latter.

The epiphytic *Araliaceæ*, nearly always also of climbing habit, do not, as far as I know, kill directly their hosts, but only weaken and deform them, in very much the same way, but to a much less extent, as non-twining climbers do.

GENERAL REMARKS.

From what precedes it will have been gathered that a mixture

of different ages is particularly favourable to the maintenance of a mixture of species. We have already seen that uniformity of age throughout a mixed crop tends to reduce the number of species, and, in most cases, to give an easy preponderance to a single one, the most tenacious and exclusive of the original mixture (Third Case, p. 82). So that the converse is also true, *viz.* that a variety of ages always promotes a mixture of species, and is often an indispensable condition for growing a mixed crop : it gives a certain chance of existence to species which would otherwise be driven out by their more tenacious and exclusive companions. A cursory examination of a sal forest, to take a common instance that jumps to the eyes, is sufficient to convince oneself of the truth of this proposition. Where the trees are all of a more or less uniform height, and, therefore, presumably of about the same age, they are almost exclusively sal ; whereas, where ages vary, many other species will be found associated with the sal, the relative proportion of those species generally increasing with the difference of ages. There can be no doubt that the pure character of the extensive teak copses of the Central Provinces, Berar, and Bombay are, in a great measure, due to a certain marked degree of uniformity of ages ; it will generally be found that the purest of these copses are those in which the trees are pretty nearly of one and the same height.

Examples of the Fourth Case.

Instances of the Fourth Case, in endless variety, are to be found anywhere in India. As some of the more important, we may point to the majority of our teak and oak forests, to a great many sal and deodar forests, to our evergreen forests, &c., &c.

CHAPTER III.

GREGARIOUSNESS AND SOCIABILITY OF SPECIES.

The terms "gregarious" and "sociable" have been defined on page 5. From the considerations developed in the Chapter just concluded, it will be evident that a *gregarious* species is one which, by its superior tenacity or exclusiveness or both combined, overcomes all its neighbours and survives all other contrary conditions in the struggle for existence, while a *sociable* species is one which, not being either exclusive or so tenacious as to yield at few or no points to its neighbours, or the sole species capable of growing in the given soil or locality, is yet tenacious enough to resist complete banishment. It hence follows that a species that is generally gregarious may nevertheless under certain circumstances become sporadic, and one that is generally sporadic may similarly become gregarious.

What we have said above will at once become apparent from a study of the few examples of gregarious and sociable trees which follow and in which the principal characters that combine to render them gregarious or sociable, as the case may be, are simply enumerated. To have attempted to explain and discuss them in a full manner would have carried us beyond the limits we have laid down for ourselves in writing the present Part of the Manual.

Sal.

This tree disappears the moment it reaches a too binding soil combined with a more or less impermeable sub-soil. Although in a comparatively dry climate it *can* grow on fairly stiff soils, the sub-soil *must always* be freely permeable. Hot winds, or excessive cold, or drought in April-May also restrict its extension. It is thus, to a very remarkable extent, wanting in tenacity as against certain unfavourable influences of soil and climate, so that its distribution is limited by sharp boundary lines; but within and right up to these limits it generally flourishes in all its vigour and is gregarious for various reasons, the principal of which are enumerated below. These reasons are so powerful, that a few of them alone would suffice to give it an easy predominance over its companions. They are —

(*a*) The peculiar nature of the tree, owing to which it generally either flourishes in all its vigour or is completely absent.

(*b*) The general aversion of cattle for its leaves, a property that saves its seedlings from being browsed down and its larger individuals from being lopped for fodder.

(*c*) Its profuse and all but annual seeding.

(*d*) The fall of its seed at the end of the season of forest fires, and at the beginning of the season of vegetation.

(*e*) The almost immediate germination of its seed.

(*f*) The immediate appearance and remarkable vitality of the collum-buds, which give its seedlings great tenacity.

(*g*) The great length and strength of the taproot developed by its seedling.

(*h*) The enormous depth (up to 60 feet and more) to which its roots can penetrate, whereby it can flourish on the driest soils, resist violent winds, and escape strangulation during its infancy and youth by the dense and stronger roots of other species, even the grasses.

(*i*) Its ability to form by itself a complete leaf-canopy.

(*j*) The persistence of its foliage during at least eleven months of the year.

(*k*) The production of more than a single flush of leaves each year.

(*l*) The ability of its young plants to persist under, and even push up through, fairly dense cover, the latter faculty being considerably strengthened by their long narrow crown.

(*m*) The early formation of a thick, sap-gorged secondary bark, which protects the cambium and dormant buds from external injuries.

(*n*) The great facility with which it grows up again from the stool.

(*o*) Its relatively great rapidity of growth from the time a certain age has been reached right up to its attaining its full height.

(*p*) The very remarkable facility with which a new leader is formed on the death or disappearance of the original one.

(*q*) The great powers of recovery of the species.

(*r*) Its winged seed, which in spite of its size and great weight, is often wafted away more than 50 yards from the parent tree.

(*s*) Its great resistance to frost, except in damp low localities.

(*t*) Its loftier stature as compared with most of its companions.

(*u*) Its great longevity, exceeding that of nearly all its companions.

Sissu.

This tree, as a gregarious species, is confined to the shingly and loose silty deposits in the beds and on the low and frequently flooded banks of Himalayan streams, where they debouch into the plains, spreading out over a great width and often branching into a number of shallow arms, which embrace between them islands of various sizes. The loose open soil, from being for a time flooded occasionally dries down to a depth of as much as twenty feet, if not more. The gregariousness of the tree is of course, due chiefly to the nature of the soil and situation in which it delights ; but a number of other causes also contribute in their respective degrees to the same end. The more effective of these various causes may be thus summarized :—

(*a*) The exclusive character of the soil and locality which the sissu affects, only khair, *Zizyphus* and a few other species being able to grow there in appreciable numbers.

(*b*) Its ability to stand extreme temperatures, especially frost, which is obviously very severe in the low and, during the cold weather, moist situations, where it grows.

(*c*) Its profuse annual, rarely biennial seeding, and the easy dissemination of its seed by water in the flooded lands where it comes up.

(*d*) The facile germination of its seeds, especially under the circumstances accompanying or rather effecting their dissemination.

(*e*) The number and great vigour of the collum-buds in the youngest seedlings, which enables these to continue establishing themselves in spite of violent floods, erosion, deposit of new silt, &c.

(*f*) Its remarkable tendency to produce extremely abundant suckers, and the extraordinary vitality of its roots in this respect, completely severed portions being able to strike and throw up shoots.

(*g*) Its germination only in loose, freshly-deposited silt, in which the young seedlings, owing to their prior appearance have not to contend with the roots of other species, especially of the grasses.

(*h*) The absence of fires in such places while the plants are establishing themselves, for the quantity of grass and other herbage that can come up in the meanwhile is naturally very limited.

(*i*) Its very rapid growth as soon as it has established itself.

(*j*) Its ability to form a complete leaf-canopy by itself during its youth, and even a dense thicket up to the close of the sapling stage.

(*k*) Its great powers of recovery from the effects of injuries.

(*l*) Its complete immunity from lopping and browsing, as its leaves are used neither for fodder nor as manure.

(*m*) The great length of the taproot of its seedling, and the great depth to which its roots can penetrate.

(*n*) The persistence of its foliage almost throughout the year.

Pinus longifolia.

The *Pinus longifolia* is a hill tree and flourishes in the poorest and driest soils, being able to attain its finest dimensions even on loosely-cemented shingly formations several hundred feet thick. Individuals of it are found as low down as 1,500 feet, and fairly large patches of it are to be met with in the moist outer Himalayan belt, but it forms really large gregarious forests only in the intermediate and dry inner belts at elevations ranging from 3,000 to 5,500 feet. The reasons for this gregariousness may, in a general manner, be briefly stated thus :—

(*a*) The extreme dryness and poverty of the soil and sub-soil, which this pine delights in, and which most other trees avoid, and the immense continuous stretches of such soil to be met with at the altitudes which suit the tree. This is the chief determining cause of its gregariousness.

(*b*) Its almost complete immunity from damage from the mouth of cattle, and from lopping for fodder, that great cause of fodder-yielding trees in the Himalayas (most of its larger broad-leaved associates are such) being entirely cut off or at least kept down in the state of low bushes.

(*c*) The very marked superior hardihood of the young seedling.

(*d*) Profuse general seeding at short intervals, with fairly abundant seeding in intermediate years.

(*e*) The comparatively small size of the pine seed, which enables it to be caught in small crevices or hollows in the hillsides, contrary to what happens with acorns, which roll or are washed down in numbers to the bottoms of the valleys and ravines, and

which are the seeds of the only companions of the pine that are at all able to compete with it in stature.

(*f*) The extremely ready and easy germination of the pine seed.

(*g*) Possession, up to the sapling stage, of numerous dormant buds, which enables the very young pine to resist fires and other extraneous causes of injury quite as well as its broad-leaved companions of equal age can.

(*h*) Its extremely thick corky bark, which protects the cambium against any but the severest external injuries.

(*i*) The remarkable vitality of its cambium and inner bark, whereby wounds are easily and rapidly healed over.

(*j*) The ability of the pine to form a more or less complete leaf-canopy up to the commencement and even middle of the large-pole stage.

(*k*) The unfavourable nature of the covering formed by the fallen needles, which opposes the appearance of seedlings of other woody species, and in some cases even keeps out grass.

(*l*) The greater relative rapidity of growth of the pine soon after it is established, and the great strength of its leading shoot.

(*m*) Its taller stature in comparison with its ordinary companions.

(*n*) The fewer enemies or causes of destruction to which its seeds are exposed as compared with acorns, which are frequently worm-eaten, rot or dry up easily, and are devoured in large quantities by bears, monkeys, &c.

(*o*) The strong rooting of the pine in spite of its being a conifer.

Anogeissus pendula.

This tree is a denizen of the dry and arid tracts of Central India, where it forms dense, almost pure forests on the metamorphic formations of the Aravali range and on the Vindhyan sandstones of Bundelkhand. Its gregariousness is due to the following combined causes :—

(*a*) Perfect suitability of the soil and subsoil and the climate, which admit of only a very poor arborescent flora.

(*b*) Its marked tendency to join and interlace crowns.

(*c*) Its profuse annual seeding.

(*d*) The easy dissemination of its small winged fruit.

(*e*) Its low, dense, spreading crown, tolerating little or no undergrowth, not even grass.

(*f*) Hence comparative mildness of fire immediately under individuals of it in forest conflagrations.

(*g*) Extraordinary powers of recovery owing to great abundance, vitality and vigour of dormant buds.

(*h*) Hence also remarkable faculty of growing up again from the stool, a single stool of less than 1 foot diameter being capable of throwing up a thick, dense clump of as many as 20—50 shoots.

(*i*) The great hardihood of its young individuals, which thrive under complete exposure.

(*j*) Singular paucity of companion species able to compete with it in size.

(*k*) The persistence of its foliage during at least ten months of the year, while the few companion species of its own stature are leafless for many months together.

(*l*) Its close and vigorous spread of roots.

(*m*) Comparatively rapid growth for the first few years of its seedlings as soon as they are established, and of its stool-shoots from the moment they appear.

(*n*) Ability to thrive on the steepest slopes.

(*o*) Greater longevity than that enjoyed by the majority of its companions.

Boswellia thurifera.

This tree is spread over the whole region of Central India, but grows gregariously as an upper crop only on the dry trap and sandstone hills and plateaux there, and forms an entirely pure forest where the amount of iron in the soil becomes marked. In this last case, the single circumstance of the soil being ferruginous excludes every other species. The causes which render the tree gregarious elsewhere may be shortly stated thus—

(*a*) Dryness, poverty, and rocky nature of the soil, which prevent most of the few companion species from rising up on the same level with it.

(*b*) Its aromatic resinous leaves, which save it from the mouth of cattle and other animals and from lopping for fodder.

(*c*) The extraordinary ease with which it produces adventitious buds on wounds ; whence in a great measure its unique power of recovery, and, therefore, of surviving the severest mutilation.

(*d*) Its faculty of throwing up strong and numerous suckers.

(*e*) Its abundant annual seeding.

(*f*) Its extremely rapid growth from the earliest seedling stage.

(*g*) Its conspicuous ability to withstand the fiercest insolation and most prolonged drought, owing to the thickness and vitality of the living bark, its viscid resinous sap and the absence of foliage throughout the entire hot weather.

(*h*) The generally mild nature of night frosts at the high situations where the tree is gregarious. This circumstance combined with the extraordinary thickness of its young shoots, the nature of its bark and sap alluded to under (*g*), and the shedding of its leaves at the beginning of the cold weather, enables the tree, which would otherwise be very sensitive, to progress upwards spite of frost.

(*i*) Its singularly great resistance to the effects of conflagrations, thanks principally to the nature of its bark, to its being out of leaf during the season of fires, to the vigour of the dormant buds, to characters (*c*) and (*d*), to its remarkably accommodating nature in respect of the quality of the soil, and to the spareness of the combustible undergrowth on the ground.

(*j*) The very low value set on its wood as timber and even as fuel, it being almost the last tree to be cut for export.

Hardwickia binata.

This is a tree of the dry tracts of Central and Southern India, but is also met with along the foot of the Kaimur Hills from Rewah to Hazaribagh. It is confined to strongly silicious soils, whatever their origin, and attains its finest dimensions on rocky rugged ground, even where there is scarcely a vestige of soil. It sometimes forms pure forests, but oftener occurs as a top-story over an open undergrowth of *Anogeissus latifolia*, *Boswellia*, khair, teak, &c. The causes which combine to make it gregarious are—

(*a*) The dryness and poverty of the soil which it affects and in which its few large companions do not develop their highest vigour.

(*b*) Its extremely profuse general seeding once in three or four years.

(*c*) The easy dissemination of its seed to several hundred feet from the parent tree, thanks to the flat light pod, which contains only a single seed and generally dehisces only after it has fallen.

(*d*) The great facility with which the seed germinates.

(*e*) The remarkable length of taproot developed by its young seedling, enabling it amongst other advantages, to grow in the midst of dense grass.

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(*f*) The persistence of its foliage during at least ten and a half months out of the twelve.

(*g*) Its producing more than one flush of foliage during the year, each accompanied with a vigorous development of new shoots, and the first of them occurring while all, or nearly all, its neighbours are leafless.

(*h*) The number and extraordinary vigour of the collum buds in the young seedling.

(*i*) The great hardihood of the young plant even without the help of the collum buds.

(*j*) The surprising ability of the young plant, thanks to character (*g*), to withstand the lowest and densest cover of its usual companions, and, with its thin flexible leading shoot, to work its way up through the overhanging crowns of those species.

(*k*) The extraordinary power enjoyed by the species of recovering from the severest mutilation, including injury by fire.

(*l*) The very much greater height attained by it in comparison with most of its companions.

(*m*) Its very rapid growth as soon as it is established.

(*n*) Its generally superior longevity.

In the immediately preceding examples we have limited ourselves to showing, without entering into any lengthy explanatory details, why the species selected for illustration are gregarious. The reasons given are sufficiently obvious after the general discussion of the Struggle for Existence in Chapter II. In the following paragraphs we will continue the application of the principles therein exposed and demonstrate, by the example of teak and *Prosopis spicigera*, how one and the same species may be gregarious or exclusive under certain circumstances and sporadic or sociable under others.

Teak where gregarious.

Over the wide area of Central India teak is gregarious either (A) on alluvial flats along the courses of rivers, or (B) on small stretches of stiffish sandy soil once under squatter cultivation, or (C) on hillsides, flats, or stretches of undulating ground, which have for centuries been subjected to the *dhaya* system of cultivation already described on page 23.

A. The soil in the alluvial flats referred to is more or less saline, with a strong proportion of carbonate and sulphate of lime, and is, in many instances, submerged for a few days every year

during the floods of the rivers. It becomes, on the other hand, extremely dry and hard for several feet below the surface, when the rivers have subsided into their normal beds during the hot weather. These characteristics of the soil and locality exclude most of the ordinary companions of the teak—*Terminalia tomentosa, Anogeissus latifolia,* khair, *Boswellia thurifera, Pterocarpus Marsupium, Sterculia urens,* &c. The few associates that follow it, *Morinda citrifolia, Eriolæna Hookeriana, Acacia leucophlæa, Casearia graveolens* and *tomentosa, Ulmus integrifolia,* &c., being beaten by it in the struggle for existence owing to the following causes :—

(*a*) The extraordinary vitality of its seeds, which the annual floods have only helped to disseminate and prepare for immediate germination from the time these silt-formed tracts were deposited.

(*b*) The constant moisture during the growing season and original absence or spareness of grass, which favoured the germination of the seeds and the subsequent establishment and development of the young seedlings.

(*c*) The rapid growth of these latter in consequence, almost from the first years up to the attainment of their full height.

(*d*) Their enormous spreading leaves, which, living or dead, suppressed every other forest seedling under, or in contact with, them.

(*e*) The thick continuous felt-like mass formed by the fallen teak leaves when saturated by rain, which mass, decomposing slowly, smothers up almost every seedling produced under it, and is impenetrable to the roots of most seedlings that germinate above it.

(*f*) The great vitality of the thick taproot and the collum buds, which enables young teak to survive forest conflagrations better than most of its companions in the locality.

(*g*) The extraordinary vigour and longevity of these collum buds, which ramify, by multiplication, even into the main lateral roots, so that these latter can throw up shoots from a depth of nearly a foot below the surface of the soil.

(*h*) The abundance and great vitality of the dormant buds in the stem of teak.

(*i*) The exceptionally great vitality of the cambium, which all but enables detached pieces of the stem to strike root and grow.

(*j*) The severity, owing to the large, woody, loosely-packed fallen teak leaves, of the annual conflagrations, which, however,

thanks to characters (*g*), (*h*) and (*i*), cause less permanent injury in teak than in most of, if not all, its companions.

(*k*) The ability of teak up to a certain age (certainly 40 years) to form by itself a complete leaf-canopy, capable of killing out all undergrowth, including even grass.

(*l*) The enormous strength and height of teak stool-shoots in their very first year.

(*m*) The existence of a more or less perfect uniformity of ages, due to the greater portion of the crop having sprung up within the short interval of years during which the alluvial flats in question were deposited.

(*n*) The conspicuously greater longevity of teak.

(*o*) Its profuse annual seeding.

(*p*) Its greater stature as compared with many of its companions.

(B) The gregariousness of teak in the second instance may be accounted for thus :—

(*a*) Profuse annual seeding of the trees round and inside the original fields, by which means the ground got sown to a certain extent everywhere with teak.

(*b*) The cultivation of the soil furnished this seed with an excellent bed, whence the production of a certain number of vigorous teak seedlings every year.

(*c*) These seedlings, possessing great vitality and throwing up shoots every year from the collum of the root, gradually strengthened themselves, and obviously suffered little or no damage from the mere annual scratching of the rude plough.

(*d*) They were obviously still further strengthened in a remarkable degree by the hand-plucking of all surrounding grass and weeds, the agricultural crop alone being never dense enough to impede their development and the wandering squatter cultivator never finding their presence sufficiently hurtful to eradicate them.

(*e*) Besides this, the extraordinary vitality of the seeds, lying in the soil in large quantities when the field was abandoned, produced an abundant crop of seedlings in the thoroughly loosened soil during the ensuing two or three years.

(*f*) On the fields being abandoned, the already established seedlings and seedling-shoots, now shooting up vigorously ahead, and thanks also to character (*d*) of the preceding Instance, suppressed most individuals of such of the companion species as were

able to reproduce themselves, like the teak, during the course of the squatter cultivation.

(*g*) See (*k*) of the preceding Instance.

(*h*) See (*e*) of the preceding Instance.

(*i*) The more or less uniform height of the various individuals, due to their having finally started upwards all together on the abandonment of the fields in question, and giving to the crop more or less the character of one consisting of trees of one and the same age.

(C) The gregariousness of teak under the *dhaya* system of cultivation may be explained by the following causes :—

(*a*) Its great powers of recovery from the worst mutilation, even in spite of annual fires.

(*b*) The remarkable faculty of its root-collum of producing shoots up to a very great age (eighty years at the very least).

(*c*) Its comparatively early seeding.

(*d*) Its profuse annual seeding.

(*e*) On hillsides, the characteristic ruggedness of the ground, which offered numerous crevices, hollows and ledges for the lodgement and germination of the large, round and heavy seed falling or rolling down from above.

(*f*) The extraordinary vitality of the seed, even when scorched by jungle fires.

(*g*) The great relative vigour of its stool-shoots, which enable them to overtop seedlings and similar shoots of other species.

(*h*) The extremely dense crowns formed by its huge spreading leaves, which tolerate no undergrowth, and push back and choke up other plants even of the same height as themselves.

(*i*) See (*k*) of Instance A.

(*j*) The contemporaneous springing up of the new stool-crop as soon as the *dhaya* cultivator departs for fresh fields.

(*k*) His practice of returning to the same place before the age at which teak ceases to form a complete leaf-canopy.

(*l*) See (*e*) of Instance A.

(*m*) The ability of young teak seedlings to withstand fairly dense cover, thus allowing an abundant advance growth to come up gradually during the absence of the *dhaya* cultivator, which advance growth shoots away upwards as soon as it is uncovered.

(*n*) The great longevity of teak.

Teak otherwise sporadic.

The three preceding instances excepted, teak is everywhere else a by no means largely represented denizen of mixed forests. The main reasons for this may be briefly summarised thus:—

(*a*) In forests which contain teak, the soil is apt to vary from point to point with regard to the proportion of clay in it, with regard to the degree in which it is monopolised by weeds with a dense invasive root-system, with regard to the degree in which the surface or subsoil rock is fissured, and with regard to the freedom of the drainage. Where the soil is too binding or not sufficiently drained or too dry for teak, or the rock is too compact, or the growth of weeds, especially the grasses, is too heavy and dense, that species will be entirely, or for the most part, kept out, notwithstanding that numerous seedlings of it may germinate in such places.

(*b*) Where the teak grows, it is almost the only tree cut for timber, furnishing, as it does, everything from the large house beam and broad boards to the thin round rafter of the rude temporary thatched shed.

(*c*) The yearling teak seedling can, as a rule, survive only on the condition that the taproot, which for many years forms the most sensitive and vital portion of the plant, has free room to expand and strengthen itself at once. Hence the death of nearly all or by far the largest proportion of the seedlings produced each year, except where the soil is especially favourable.

(*d*) A great many of the companions of teak are more shade-enduring than itself.

(*e*) Most of its companions in the ordinary soil of the forest establish themselves earlier, and thus possess themselves of the soil while young teak of their own age are still comparatively weak plants.

(*f*) In many places several of its companions exceed the teak in stature.

(*g*) Many of these species possess broader and deeper crowns.

(*h*) Many of them also retain their foliage till a later date, and some of them even bring out the new season's flush earlier.

(*i*) After a certain age teak loses the faculty of forming a complete leaf-canopy by itself, thus necessarily giving entrance to other species even where it originally formed a pure crop.

(*j*) Its seed, being large, does not find easy lodgement in the soil, unless this is loose at the surface, and, being also round, is

exposed to be washed away by the first heavy showers, especially where forest fires occur.

(*k*) Again, as the seed is all shed by the middle of the hot weather, the greater portion of it used every year to be destroyed by the annual forest fires before special protective measures, of very recent date, began to be undertaken, and is still so destroyed over the vast areas where fire conservancy is either unsuccessful or has yet to be introduced.

(*l*) In most parts of India proper, the teak is characterised by tardy and difficult germination, the seed either requiring to lie in the ground for at least a whole year exposed to weather influences and other causes of destruction, or sprouting too late in the rainy season to be strong enough to survive through the following dry season or escape strangulation by the heavy growth of weeds and other vegetation already on the ground.

(*m*) The seed is the common food of many rodents, parrots, &c.

(*n*) The young plant is exrtemely sensitive to frost.

(*o*) The upper portion of the taproot of the seedling is greedily devoured by rats.

(*p*) Some birds, as the bush-quail, peck off the cotyledonary leaves with the terminal bud, as soon as these appear.

Prosopis spicigera.

This species, thanks to the enormous length of taproot (60 feet and upwards) it can develop, is peculiarly a tree of very dry regions and ceases where the rainfall exceeds 40 inches. In the Panjab and Rajputana, with a rainfall varying from 12 to 25 inches, it is gregarious on high ground, where, the depth of the stratum of permanent moisture being very far below the surface of the soil and the subsoil being strongly saline or consisting of shingle and boulder beds, no other trees or even large shrubs can grow. Descending towards the main drainage channels it is obliged to yield a less or greater portion of the ground to other trees. In Sindh, where the rainfall is less than 10i nches, the pure *Prosopis* forest approaches much nearer to the streams, but still remains above the level of inundations. In Bundelkhand and from the Narbada southwards, and in the proximity of rivers elsewhere, the tree is no longer gregarious, the very much diminished distance below the surface of soil sufficiently moist for vegetation enabling other species to grow side by side with the *Prosopis*, and in many, if not in most, cases to preponderate over it, thanks to their larger sta-

ture, their more shade-enduring capacity, their greater resistance in those comparatively moist soils to frost, the rocky subsoil, and some other characters which vary with the region and the locality.

Concluding Remarks.

We need not multiply the preceding instances to prove that the gregariousness or sociability of a species is purely the outcome of its struggle for very existence with other species and with the opposing conditions of climate and soil. The fittest will everywhere survive. But the fittest species not being necessarily also the most valuable (whether absolutely so or because they favour the growth of those which are), we, as foresters, have often to intervene in the struggle and aid the weaker to conquer the stronger. Hence the most practical end intended to be served by the considerations developed in the present and immediately preceding Chapters is that they may furnish us with the key wherewith to study and analyse with sufficient exactness the behaviour of each one of our more valuable species in that struggle, to note under what conditions it can hold its own against all its rivals, under what circumstances it has to yield to its stronger neighbours, to what extent and how those circumstances may be favourably modified by the forester, up to what point the struggle is useful in drawing up the trees, in naturally forming their boles, or in any other way improving their growth or the quality of their timber. Armed with such facts, we can, with the full confidence that knowledge begets, interpose with the most appropriate effective measures, as soon as the necessity arises, to shorten or prolong the struggle as the case may require, and to continually aim at securing the most advantageous proportion and distribution of the various species and age-classes—in other words, attain the main end and object of Sylviculture, which are *the largest and most useful production in forests grown for the market; the most effective living tree covering or barrier, combined, whenever possible, with a large and useful production, in forests grown for protection; and the most pleasing effect on the eye in forests grown for ornament.*

CHAPTER IV

SPECIFIC COMPOSITION OF FOREST CROPS.

Ought we to grow pure or mixed forests? This question has already been partially answered in an incidental manner in Chapter II; but it is of such importance to the forester, that it demands special and full treatment here.

A forest may be grown either exclusively for the market, or essentially and chiefly for purposes of protection, or essentially and chiefly for ornament. The answer to the question heading this Chapter must hence be sought separately in each of these three several cases. But before attempting to do so, it is necessary first of all to enquire what peculiar advantages or disadvantages accompany the mixing of species, or the growing of them pure.

SECTION I.

Characteristics of pure and mixed crops compared.

The advantages to be derived from growing mixed, as compared with pure crops, are briefly as follow :—

I. A mixture of species generaly allows of a more complete utilisation of the area.—It extremely rarely happens that the soil and locality are at every point either only suited for a single species, or capable of growing that species better than all others. Hence with a mixture of species it is always possible to grow at any particular point only those species which thrive well there, and thus turn the entire area to the best account possible.

II. Mixed crops, as a rule, form a denser leaf-canopy.—In a mixed forest the various species attain different statures, develop crowns of different shapes and width and depth, are shade-enduring or shade-avoiding in different degrees, possess foliage of various degrees of closeness, affect or prefer different soils and situations, bring out and shed their leaves at different times, and so on. The obvious result is that the leaf-canopy is then composed of crowns of various shapes and sizes, situated at various heights above the ground, and fitting into one another not unlike the

gravel and stones in concrete, thus generally forming a closer-packed mass of foliage than if the forest were composed entirely of any single one of the same species as constitute the mixed growth. Then again in every forest, whether pure or mixed, the number of stems standing must necessarily diminish progressively with advancing age by the death and disappearance of some of the trees. Now in a pure forest, unless the component species be extremely shade-enduring, the intervals thus produced between the similarly-shaped crowns of the surviving individuals are bound to become rapidly wider and wider, until at a comparatively early age the trees, all more or less of one and the same height and habit of growth, stand well apart from one another and cease to protect the soil except in a very incomplete manner. In a mixed forest, on the other hand, during a considerable part of its life, the gap produced by the disappearance of any one of the trees will nearly always be at once filled up by the upward growth of those immediately below, or by the lateral extension of the adjacent crowns, chiefly of individuals of other species possessing a different habit of growth. Hence not only does the greater density of a mixed forest become, as a rule, more conspicuous with increasing age, but mixed crops generally maintain a complete leaf-canopy up to a more advanced age than pure ones of the same species, an unquestionably great advantage for the forester in almost every instance.

III. A judicious mixing of species increases the amount of ligneous production.—For the same reasons that the leaf-canopy becomes denser, and also because of the different root-systems of the various component species, the number of stems standing per unit of area at any age becomes larger. Besides this, the greater density of the leaf-canopy not only produces longer boles, but, by improving the soil, also prolongs the period of sound growth. All these circumstances result in a larger production of wood, and more particularly of timber.

IV. It is only by a mixture of species that with regular annual working we can cultivate our more valuable species in the greatest abundance within any given area, over the widest extent of country possible, and of the finest quality and size.—Many of our most valuable species, like teak, *Dalbergia latifolia Lagerstræmia Flos-Reginæ*, &c., and, in many localities, even deodar and sal grow naturally in company with other trees. If we

sought rigidly to obtain pure crops, we should either have to clear away all these latter, and leave a few isolated individuals or patches of the former to form the sum total of the standing growth; or, if we insisted on having a full growth on the ground, we should have to cut away every individual of those valuable species from wherever they could not grow gregariously, thus restricting them to those places alone, of limited extent and few and far between, where they could do so—the one result being as much to be avoided as the other. On the other hand, by studiously preserving and favouring the growth of every individual of all our valuable species, whether it stands by itself or in company with others of its own kind, provided it does not interfere with the growth of another more valuable than itself, we produce in the largest quantity possible, the classes of timber and wood most in demand and also spread their production over the widest extent of country possible, thus raising them everywhere as near as practicable to the consumer.

Then, again, as a mixture of species, by producing a denser leaf-canopy, improves the soil, forms long and well-shaped boles, and delays the commencement of natural decay, our valuable species are enabled thereby to acquire their finest qualities, and attain their largest dimensions. So that any one of them, grown in company with another soil-improving species (*i. e.*, one which puts forth abundant foliage, that decomposes easily and yields a rich humus), will furnish timber of good size and quality even on soils on which it could not thrive alone. Thus we know that sal, deodar, and especially teak, acquire much finer dimensions in mixed forests than when growing pure, and this most conspicuously on soils that are in themselves more or less unfavourable for their growth.

V. A judicious mixing of species furnishes produce suited for a greater variety of purposes, and hence giving occupation to an absolutely as well as relatively large portion of the industrial classes of the country.—This is especially so in advanced communities. We in India are still in a very backward condition. But the signs of the times are already encouraging, and in many parts of the country various woods, which only a few years ago no one would literally look at, are now coming into the market; while for some of them there is an established and rapidly increasing demand. In many parts of Berar and Central India the *Boswellia thurifera* is readily bought up at high rates in the shape of boards for flooring and packing cases, and as building

wood, although only half a generation ago there, and at the present day elsewhere, the wood of that species was or is despised even as an occasional fuel. The timber of *Terminalia tomentosa*, which used generally to be a drug on the market, is now universally valued for railway sleepers. The formerly, and in many places still, despised *Pinus longifolia* is now exported in large quantities from the hills into the Punjab plains, and passed off as deodar on people who judge things only or chiefly by their names. In some parts of the Central Provinces, *Ougeinia dalbergioides* poles command higher prices than teak of similar size. In the vicinity of spinning factories *Zizyphus Jujuba*, which formerly served chiefly for fuel and fencing, is now in great demand for cotton-mill spindles. Such instances may be indefinitely multiplied. We have in India unlimited resources for cabinet-making, for the manufacture of matches and paper, and for numerous other wood-using industries. Enterprise and time will soon show us how to employ them.

VI. A mixture of species tends to increase the production of minor produce, such as seeds, fodder, flowers, bark, leaves, and fruit for tanning and dyeing, &c.—As a rule, it is the young tender leaves of trees that are used as fodder for cattle. Now in a mixed forest the various trees bring out their new foliage at different periods of the year, so that a more continuous supply of fodder is thereby assured. Moreover, in such a forest, some of the species, being of a low habit, or not being valued for their wood except as fuel, can often be lopped without any appreciable detriment to the standing growth, and must even frequently be so lopped for the improvement of this last. Nay individuals of the more valuable species themselves must very often be cut out or lopped in order to favour the development of the rest. Most trees and shrubs yielding dyes, material for tanning, &c., unless specially cultivated, cannot grow gregariously and form pure crops. And so on.

VII. Many kinds of trees are less liable to damage in mixed than in pure forest from storms, fire, frost, drifting or superincumbent snow, hidebinding, insects, game, cattle fungi, and diseases in general.—In company with a deep-rooted, species, another with superficial roots is able to resist storms almost as well as the former. Even superficially-rooted species protect one another when mixed, by reason of the denser leaf-ca-

nopy and closer growth they then form than when they grow pure. For the same reason the chances and destructiveness of fire are diminished in a mixed forest. This is especially the case in crops of mixed conifers and broad-leaved species as compared with those of conifers alone. In forests containing conifers, an admixture of broad-leaved trees, the crowns of which are larger and composed of more numerous, stouter, less horizontal, and generally also more elastic branches, and the roots of which are stronger and better ramified, affords very great protection to the former against damage by snow and wind. Then, again, as insects often attack only sickly trees (which are relatively not numerous in mixed forests), and not unfrequently confine their depredations, when they do attack healthy individuals as well, to a single or only a few species, their ravages are naturally not so extensive in mixed as in pure forests. And if the forests in question contain conifers, the companionship of broad-leaved trees is specially beneficial in that the numbers of the natural enemies of insects (birds, rodents, &c.) are generally increased by their presence. Again species, which in early youth are delicate, find much more protection against frost, drought, &c., in a mixed than in a pure forest. Another beneficial effect of mixture is, that it contributes very materially towards the diminution of diseases of which the attacks of fungi are either the symptom or direct cause. Lastly, trees, the leaves of which are eaten by cattle or deer, run less risk of being browsed down when they grow here and there mixed with other species than when they all stand together as they do in pure forests.

VIII. The relative suitability of the soil and locality for our various species is most easily recognised when they are growing together, so that the forester has then no difficulty in ascertaining at once, and with certainty, what species to grow or favour in any given soil or locality.—This advantage is especially emphasized in a new country like India, where so little is yet known of the habits and requirements of even our principal species, and it becomes most conspicuous when sowings or plantations on a large scale are to be made. Mistakes committed in executing the various forest operations can be detected much more easily in mixed than in pure crops, and generally, if not always, early enough to prevent any serious or further damage.

IX. When a forest is regenerated naturally, its regeneration

is better assured if it is mixed.—Seeds of one species or another are sure to be produced in less or greater abundance every year all over the forest. A great number of these must germinate, and, wherever sufficient light reaches the ground and other conditions are favourable, a large proportion of the seedlings thus produced must establish themselves. Moreover, as the seeds of different species germinate with different degrees of facility and require different degrees of heat and soaking, it is certain that, whatever the character of the season of vegetation may be, some seedlings cannot fail to be produced every year. Thus in mixed forests regeneration is continually going on with more or less vigour, and success depends to a less degree on the forester's care and skill. It does not, however, follow that in the new generation each species is represented to an extent proportionate to its relative value or desirability.

X. In a mixed crop mistakes are generally less fatal in their consequences, and usually correct themselves, or are corrected by the forester, more easily than in a pure crop.—In the case of overfelling or the excessive opening out of the leaf-canopy, the presence of trees of various habits and requirements is the best guarantee we can have for the early restoration of the leaf-canopy or forest, as will be evident from the considerations developed under preceding heads II, VII, VIII, and IX. The beneficial effect of this on the soil is invariable and undoubted, but, where nature is unaided, we have no assurance that the canopy or forest will not be mainly reformed by the less valuable and even undesirable species at the expense of the more valuable ones.

XI. Mixing species in a forest economises labour and time and facilitates work and supervision.—Given a certain definite area of forest and certain species to be grown there. If these species are raised pure, they will of course occupy as many distinct sections of the area; so that if an annual supply of the wood of each species were required, a portion of each section would have to be worked every year, thus creating so many independent centres of work. But if all these species were intermixed, the same result would be obtained by working at only a single point every year, and then the whole area would be divided into a single series of coupes of convenient extent, instead of innumerable small patches very difficult to look after and work, because those taken in hand in any given year are necessarily scattered here and there

without any definite order all over the forest.

XII. A mixture of species contributes in various ways towards equalising the length of the rotation required by our various species.—A species that protects the soil very imperfectly after a certain comparatively early age has been reached, must, if growing pure, allow it to deteriorate, unless the crop is at once cut and regenerated; otherwise the soil, deteriorating on account of the imperfect leaf-canopy, must necessarily react on the species, and thus weaken and arrest its growth, and induce premature decay. A soil-improving species, on the other hand, even if growing pure, will never fail to attain the finest growth of which it is capable on any given soil, which it will perforce gradually render more and more suitable for itself. Now mix both species together, and thanks to the improvement of the soil effected by the latter, and to the denser leaf-canopy and the maintenance of favourable influences due to the mixed growth, the longevity of the first must obviously be enhanced.

XIII. By a mixture of species a forest is generally able to yield marketable produce at an earlier age than if it consisted of pure crops.—The reason is obvious. The trees, thriving better, often acquire, in spite of the closer growth, a given size at a younger stage of development. But, what is more to the point, as the stems in a mixed forest are more numerous, the first series of exploitations to check and control the struggle for existence become necessary much earlier. Besides this, in a mixed forest, owing to the different habits of the trees and their different requirements as to light, not only does a given number of stems form a denser leaf-canopy than in a pure forest, but a gap made in that canopy is sooner filled up; so that, with no heavier stock on the ground, the first cuttings may be made earlier there.

XIV. Mixed forests, as a rule, yield a larger revenue than pure forests, provided of course that the component species are all marketable.—This follows directly from all the preceding considerations.

XV. A mixture of species gives greater elasticity to the working and treatment of a forest.—Yielding a great variety of products, a mixed forest can be worked in almost any condition of the market. Containing various species, and thus composed of individuals possessing various capabilities, it may be adapted at once

to more than one method of treatment, or, at any rate, allow of the rotation, the method of treatment, and even the régime, being changed without difficulty or loss of time. On the other hand, when there is only a single species in the crop, the lines on which work must be carried on are necessarily very inelastic, and every thing must be done with a more or less mechanical regularity, little scope being left for altering the system of management from time to time in order to suit the ever-changing conditions of the country and the market.

XVI. A mixed forest will, unless the soil suits only a single species, invariably afford better protection against erosion of the soil, landslips, avalanches, hot, cold or violent winds, &c., than a pure forest growing under identical conditions.—We have already seen that in mixed forests the leaf-canopy is denser, the number of stems larger, the mass of roots in the soil thicker and closer and the individual trees themselves more resisting ; hence the fact enunciated at the head of this paragraph.

XVII. Mixed forest generally adorns the country more and is also more attractive than pure forest, and thus affects beneficially the physical, æsthetic, moral, and mental development of the people.—This advantage is not to be despised, and is by no means of slight importance in its effects on the genius of a people. The finest poetry has had its inspiration from the forest. The manliest portion of a nation is generally that which inhabits the interior or the borders of forests. The beneficial influence of forests is seen in the universally admitted necessity of people's parks, &c. in civilised communities.

Having enumerated the various advantages offered by a mixture of species, we will now briefly enquire in what respects, if any, and to what extent a pure crop is to be preferred.

In the first place, the treatment and management of a pure forest are simpler, since in it we have to study and satisfy the habits and requirements of only a single species. This greater simplicity is more particularly apparent in the raising and exploitation of the component crops, the successful accomplishment of which operations, on that account, makes less demand on the experience, skill, judgment and resource of the forester than when mixed crops have to be dealt with. This is doubtless a very great advantage in a backward country like India, where for many years yet, until no more than the principal species have been thoroughly studied

and a large, qualified establishment has been organised, rule of thumb must be largely followed. But it is not to be construed into a universal reason for invariably and deliberately converting every existing mixed forest into a pure forest, and it can no more than serve as a plea for not being in too great a hurry to introduce a mixture into an existing pure forest without some strong justification.

In the second place, when there is only a single species the wood of which is marketable, as unfortunately happens, for the present at least, in the case of only too many of our forests, a pure forest of that species, if it can be raised or is ready to hand, is very desirable; otherwise, except with the aid of special operations, always difficult and often prohibitory from the point of view of cost, that species must either disappear altogether or be ultimately reduced to a few wretched unexploitable individuals. This consideration is a much stronger plea for pure forests than that discussed in the preceding paragraph, but here also, as in that case, the possibility of creating or maintaining a pure forest, without any risk of some strong countervailing disadvantage or disadvantages must be previously assured.

SECTION II.

Composition of forests grown exclusively for the market.

In raising and cultivating such forests, the main object to secure is to obtain the maximum and most useful production of which the soil and climate combined are capable.

To obtain the maximum production alone the following conditions must co-exist :—

(i) *The forest must be composed of the most suitable species for the given soil and climate.*—Both these elements usually vary from place to place and often even from point to point, and the species must of course vary accordingly, since there is no single one that will grow equally well under constantly changing conditions of soil and climate. Hence advantage in a *mixture of species*, save perhaps in the very exceptional case of the more or less perfect uniformity of both these factors of vegetation.

(ii) *The forest should consist of the 'greatest' number of stems possible at any given stage of growth.*—This is secured by constantly maintaining as complete a leaf-canopy as possible—a result, as shown under Advantages I, II and III of a mixture of species

(pp. 108—109), best attained by means of a *mixture of species* possessing different habits, different requirements as to soil, situation, and aspect, and a different ramification and spread of roots, besides making different rates of growth, and reaching different statures.

(iii) *The trees should attain the greatest length of bole possible under the given conditions of soil and climate.*—This end also, as explained under advantages II and III, (pp. 108—109), is best secured by a *mixture of species*, thanks to which the trees attain various heights, their crowns press one against another, and the depth of the leaf-canopy is always maintained at its maximum, the result being forcing in height and rapid elongation of the boles up to the maximum limit possible for each species.

(iv) *We must have continual improvement of the soil until its maximum fertility is reached, and constant maintenance of that maximum thereafter.*—To secure this end we must have—

a. An abundant annual production of foliage yielding a rich humus.—When *several species grow together*, they form not only a denser but a deeper mass of continuous foliage, the obvious consequence being a more abundant production of leaves, area for area, than if the forest were pure. Besides this, we know that some trees produce more foliage than others, *e.g.*, sal and *Terminalia tomentosa* than teak ; in the hills, the oaks, deodar, and the firs than *Pinus longifolia* ; and so on ; and that the leaves of some decompose more easily and form a richer humus than those of others, *Terminalia tomentosa* and sal, for instance, being better in this respect than teak, and the oaks than *Pinus longifolia* or any other conifer, and so on. Hence with a *mixture of species* there is always a better chance of the soil being continually enriched by the decomposing leaves.

b. The, as much as possible, constant maintenance of a complete leaf-canopy.—This would protect the soil, including its covering of dead leaves (1) *from erosion and breaking away* ; (2) *from the sun's rays*, which would dry up the soil rapidly and hinder the formation of humus ; (3) *from winds*, which would blow away the covering of dead leaves, besides accelerating the evaporation of moisture from the soil ; (4) *from the action of directly falling rain*, which would wash away the surface-soil and covering of dead leaves and humus, besides carrying away in abundance from the soil soluble substances fit for plant food ; (5) *from being over-*

run with weeds, which would be an obstacle to reproduction, and would choke out, or at least keep back, advance growth; and (6), *to a certain extent, from fire*, which would burn less fiercely if the soil and covering layer of vegetable debris were kept moist as much and as long as possible, and the production of a strong draught of wind, in case a conflagration occurred, were impeded. All these various objects would be most completely attained by means of a *mixture of several species*. If the species composing a forest are all, or most of them, deciduous, some of them, at any rate, are sure, or at least very likely, to be in leaf while the others are still bare, and thus a green canopy (imperfect it may be, but nevertheless a green canopy) will be secured during as many months of the year as possible; whereas, when there is only a single species, and that a deciduous one, the whole forest may be leafless for a consideraale time, and the soil completely exposed to injurious weather influences and liable to run wild with weeds.

c. *Prevention of fire*, which would, besides destroying all the organic matter in the topsoil, bake its surface hard. As shown under Advantage VII, p. 103, a *mixture of species* diminishes the chances and the destructiveness of forest conflagrations.

(v) *The forest must be rendered as safe as possible against storms, fires, insects, hide-binding, snow and other causes of destruction or malformation of the trees.*— It has already been explained under Advantage VII, p. 111, that this end is better secured in a *mixed* than in a *pure* crop.

(vi) *Besides wood, the forest should also yield fodder, fruit, and other minor produce*, which would be generally furnished in greatest abundance by a mixed growth, as shown under Advantage VI, page 111.

In order to secure, besides *the maximum production*, also *the most useful produce* of which the soil and climate combined are capable, the following additional conditions must exist simultaneously with all the preceding :—

(vii) *The forest should be composed only of marketable species, the largest proportion possible; if the forest is mixed, being assigned to the most valuable (principal) species, consistent with the realisation of all the other conditions.*—The necessity of this condition is obvious. The question of purity or mixture will depend exclusively on extraneous circumstances, such as the adap-

tability of the soil for one or more species, the limitation of the demand to a single species or not, &c.

(viii) *The forest should, if possible, consist of a mixture of species.*—Mixed forests yield more varied and, therefore, more widely useful produce. Different industries require different descriptions of wood and other forest products; and our aim ought to be to satisfy all present and possible future requirements with the least amount of delay, inconvenience and expense to the State and people, and of departmental disorganisation and sudden dislocation of routine. A judicious mixture of species, whenever it is feasible, is the surest means to this end.

(ix) *The trees should, unless curved timber were specially required, be as long and as straight and clean-boled as possible.*—This end is generally best attained by a mixture of species whereby, as explained under Advantages II and III, pp. 108-109, the closer and more vigorous growth results in the formation of long, well-shaped and straight-fibred timber.

(x) *The wood produced should be as sound as possible.*—In the discussion of Advantage VII, p. 111, we have already seen that in order to secure this object a mixture of species is, in nearly every case, to be preferred.

SECTION III.

Composition of forests grown exclusively or principally for purposes of protection.

In such forests we require in an essential manner the most effective living vegetable covering or barrier; and, if in addition to this, we also obtain, wherever possible, a large and useful production, so much the better.

To secure the first object, we must have the following conditions:—

(i) *The forest should be composed of the most suitable species for the given soil and climate.*—This is the first conditon discussed in the preceding Section.

(ii) *The forest should consist of the greatest number of stems possible at any given stage of growth.*—This too has been already discussed in the preceding Section as Condition (ii).

(iii) *The leaf-canopy should be as full and as deep and near the ground as possible.*—This end will be attained by a mixture of various ages, and still better by a mixture of ages and species

(iv) *We must have continued protection and improvement of the soil until its maximum fertility is reached, and thenceforward the constant maintenance of that maximum.*—This condition also has been fully considered under the same number in the preceding Section.

(v) *The trees should afford each other mutual security against all extraneous accidents.*—This is only a slightly modified form of Condition (v) of the preceding Section.

If in addition to the above conditions, the trees acquire the greatest length of bole attainable (Condition iii of preceding Section), are all marketable (Condition vii of preceding Section), yield minor produce besides wood (Condition vi of preceding Section), furnish long, clean and well-shaped timber (Condition ix of preceding Section) and belong to various species (Condition viii of preceding Section) the forest, besides fulfilling in the most complete manner its special and original rôle of affording protection, will also furnish a large quantity of useful produce.

SECTION IV.

Composition of forests grown essentially and chiefly for ornament.

The question of the composition of such forests belongs to the province of landscape gardening and trenches on the sylviculturist's ground only when considerations of production and income are connected therewith. A straight, clean-boled, sound tree, the sylviculturist's ideal, is not necessarily the handsomest tree on every or even most occasions; but there are few proprietors who can afford to neglect such considerations, and it hence results that in the great majority of cases deviations from the rules of sylviculture are allowed only when they do not involve a serious less of production. Wherefore, while constantly aiming at the beautiful, the landscape gardener must adhere, as closely as the special circumstances will allow or necessitate, to the various conditions enunciated in Section II of this Chapter.

SECTION V.

When forests may be grown pure.

From the considerations developed in the preceding Sections of the present Chapter, it is obvious that the raising of pure forests is to be generally avoided. Under certain special circum-

stances, however, forests (A) *may* or (B) *must necessarily* be grown pure.

A. It may be laid down as a general rule that a species *may* be cultivated by itself only when the following three conditions are realised at one and the same time:—

(i) *It should be able to form of itself a complete leaf-canopy up to an advanced age, certainly not much below that at which it becomes fully fertile;* for under no other circumstance would (*a*) the fertility of the soil be increased or maintained, (*b*) the natural pruning of the boles of the trees intended to furnish timber be effected to the desired extent, and (*c*) the forest yield anything approaching the maximum amount of produce of which it is capable. Where regeneration is required to be effected mainly or exclusively by natural means, this condition is *a sine quâ non*, otherwise grass and other injurious invasive vegetation would take possession of the ground as soon as the leaf-canopy began to clear itself.

Exceptions to the foregoing Rule:—

The preceding condition is not obligatory—

(1) If the forest is exploited on a very short rotation.—During their youth all trees protect the ground well enough, since the young stems not only bear standing close together, but also possess low crowns almost reaching down to the ground. Teak coppice furnishes a good instance of this: under a full crop, say of from 800 to 1,000 stems per acre, not a single blade of grass can make its appearance. A bamboo brake is another excellent instance in point.

(2) When the soil is such that its fertility is not impaired by a defective covering of trees.—We may instance marshy land, to which the admission of sunshine and wind is, in truth, beneficial, and the bottoms of many valleys, as well as many lowlying places, which always remain moist or wet in consequence of their situation, and in which the soil is always deep, rich, and free, thanks to the humus and vegetable debris continually washed down from the higher surrounding ground. Even in the case such soils, it is desirable that the single species chosen to be raised should be as shade-enduring as possible, so as to form a more or less complete leaf-canopy.

(ii) *The effective factors of soil and climate should be uniformly favourable for its prosperous vegetation over a more or*

less extended area.—Unless this area were absolutely large, the pure crop thus composed could scarcely be considered more than a mere patch of trees forming a small part of a much larger whole of truly mixed forest.

(iii) *The produce furnished by the given species should either be in such great demand that every square inch of the soil ought to be devoted to its cultivation, or possess such a high market value that the cultivation of any other species in mixture with it would result in an appreciable loss of possible revenue.*

The preceding three conditions would not unfrequently be realised in certain stretches of sal forest, in tun plantations on extremely favourable ground, &c.

B. It has just been explained under what circumstances a species *may* be grown pure. In the following case, and only in that, there is no alternative but to raise pure forests :—

When the soil is such that no other species, whether marketable or not, will grow on it; for example, the stretches along the Indus, which tamarisk or babul alone can occupy; along streams at the foot of the Himalayas, where sissu or khair only will succeed; some of the laterite tracts in Burmah, where eng is the sole tree; and so on.

CHAPTER V.

CULTIVATION OF MIXED CROPS.

In cultivating mixed crops we must first of all thoroughly understand what conditions are necessary to ensure a permanent mixture, for otherwise a crop raised originally as a mixed crop and intended to remain such, may eventually sooner or later become of itself transformed into a pure one. When these conditions have once been thoroughly understood, we must next know how to create and treat a mixed forest in any given case. We will now discuss these questions from a general standpoint, and conclude the Chapter with an enquiry into the characteristics of a good auxiliary species.

SECTION I.

Conditions necessary for a mixture of species.

In a general manner it may be said that the possibility of obtaining and maintaining a mixed growth depends—

1. *On the suitability of the soil for the more or less prosperous growth of more than one species.*—Many large stretches of laterite in Burmah practically exclude the existence of other species with the eng, save in specially favourable localities. In the Central Provinces certain ferruginous soils can bear nothing but *Boswellia thurifera. Terminalia tomentosa* occupies almost by itself patches of stiff, wet soils in the immediate vicinity of sal and teak forest. And so on. It is not enough if two or more species can simply grow in a given soil, nor is it at all necessary that the soil should at every point be equally suited to all the associated species; what is wanted is that their vegetation on it should be vigorous enough to enable them to survive in the struggle for existence with little or no extraneous aid on the part of the forester.

The infringement of this the first condition, must necessarily result in the originally mixed crop becoming ultimately pure, with the consequence that the forest growth must with advancing age, become increasingly more open than if no mixture had been originally attempted, in which case a pure forest from the outset would obviously have been preferable.

2. *On the suitability of the climate and locality for the more or less prosperous growth of more than one species.*—This is self-evident. The expression "more or less prosperous" must be understood here in the same sense as in the discussion of the preceding condition.

3. *On the ability of the mixed species jointly to maintain and improve the fertility of the soil.*—If the mixed growth were such that the soil deteriorated under it, then the proportion of some one species, the hardiest and most tenacious of the mixture, would, in the majority of cases, gradually increase to the detriment of the rest, and in time the crop would consist wholly, or almost wholly, of that species.

4. *On the requirements of the several species as regards light being different.*—All woody species require light in order even to simply remain alive, but some can endure shade better than others, as has already been seen in the Chapter on the Struggle for Existence. The ability of a plant to endure shade is usually proportionate to the density and shape (spread and depth) of its crown, as well as to the height of the latter above the ground. If all the associated species possessed the same requirements as to light, the mixture would be no better than a pure forest, and, unless the species in question were extremely shade-enduring, the condition of the leaf-canopy must ultimately become more or less unsatisfactory.

5. *On the relative hardihood of the several species.*—The hardihood of the various species during their youth is very various, and depends in a great measure on the character of the locality and soil in any given case. In certain localities, and in certain soils, some species cannot do without the protection against frost and drought afforded by shelter and cover, while others again, although able to grow up in the open, nevertheless thrive better when sheltered. It must never be forgotten that relative hardihood is modified by the nature of the soil and the climate.

6. *On the relative rapidity of their growth in height at various ages, especially during their youth.*—It matters a vast deal whether in a mixed crop the more shade-enduring species grow up with greater, equal, or less rapidity than the rest; and the importance of this consideration is naturally greater during their youth than at any other time. To take only a single instance, if the crop consisted of individuals of more or less the

same age or height, it is obvious that the more rapidly growing species, provided they were also the most shade-enduring, would as soon as they had joined crowns over the rest, kill or at least permanently throw back these latter; while, if the crop were quite young, these must be entirely killed out wherever the former were numerous enough.

7. *On the quantity and spread of the roots of the several species.*—This circumstance always possesses a considerable degree of importance. Some species will always develop a larger mass of roots and rootlets than others. The main roots of some will work their way on horizontally, while those of others will, for the most part, run along through the ground obliquely, and sometimes (as in the well-known instances of sal and jand) even vertically, being thus able to draw nourishment from the deeper layers of the soil. The roots and rootlets of some species are invasive, while those of others, especially while in the seedling stage, wither away in too close contact with the same organs of another species with which they may be growing. These various characteristics and requirements of the roots of the several species intended for association should be thoroughly considered and allowed for.

8. *In the majority of instances, on the presence of different-aged individuals.*—This point has been explained in sufficient detail under the head of "General Remarks" on pages 83 and 93.

9. *On the characteristic form of the crop and its mode of origin or regeneration.*—As regards its form a crop may consist of only a single story of growth or of two or more stories one above the other; or it may consist of a single story with an occasional higher tier here and there, or with no individual stems so much more advanced than all their neighbours as to stand in a distinct and isolated manner above them; and so on. For instance, it is easy to understand that certain species may be able to grow in company with certain others only on the condition that after a certain early age they have their crowns completely exposed overhead and more or less free laterally. Then, again, the mode of origin will obviously influence very considerably the permanence or otherwise of a species. Thus under a strictly simple coppice régime, species producing the strongest shoots or suckers must predominate to the detriment of all the rest; under an exclusively high forest régime, the earliest and most profusely seeding species may get the upper hand of every other; and so on. To sum up what pre-

cedes, the form of the crop and the mode of raising or regenerating it should always be so chosen as to suit the mixture in the particular case in question.

10. *On the relative tenacity of the species to be mixed.*—This is too self-evident to require explanation.

SECTION II.

General rules for growing mixed crops.

We may now lay down the following general rules to be observed in growing mixed crops:—

I. *The predominant species, whether there be several or only one, ought to be soil-improvers.*—If the principal species is itself a soil-improver, then the more it predominates up to the limit at which the crop would become pure, the better in almost every case. But if it is shade-avoiding, then from the time it ceases to form of itself a complete canopy, the auxiliary species ought to predominate to the extent of filling up all the intervals left between the crowns of individuals of the former. Of course the best way in which this predominance could have effect would be if the auxiliary species constituted a complete understory of growth so as to leave the crowns of the more valuable trees as free as possible to get the full benefit of the sunlight. When the principal species is a conifer, howmuchsoever shade-enduring it may be, we have a slight modification of the general case owing to the peculiar nature of the leaves of that family of trees, they being, in fact, strongly fibrous and resinous and hence decomposing slowly and forming a bad humus. On this account, in conifer forests it is *always* desirable to have as complete an understory of broad-leaved auxiliary species as possible, quite irrespective of the proportion of coniferous individuals present.

II. *Shade-enduring species may be intermixed, if they enjoy the same rate of growth in height, or if the slower growers can be protected against the more rapid growers.* This protection can be secured either—

(*a*) By their artficial cultivation a certain number of years in advance of the latter; or

(*b*) By their being able to produce naturally an abundant advance growth under the old standing crop, while the more rapid growers can be reproduced naturally in adequate numbers only by means of special regeneration fellings, and by that means gaining a sufficient start on these latter; or

(c) By their cultivation, whether artificial or natural, in sufficiently predominant numbers; or

(d) By pruning and lopping off overhanging branches of taller growth of other species, or by keeping it down by topping or cutting back wheresoever and whensoever necessary.

III. *A shade-enduring (in other words, dense-crowned) species may be intermixed with a shade-avoiding (in other words, spare-crowned) species, when this latter grows more rapidly or is given a sufficient start ahead of the other:*—The start must, of course, be sufficient to prevent its being ever outstripped and thereby overtopped.

IV. *Shade-avoiding species ought not to be intermixed by themselves in any permanent manner:*—For in crops so composed the soil is not only bound to degenerate (violation of Rule 1), but the slower growers must inevitably be suppressed by the rest.

Exceptions to this Rule:

(1) On a fertile soil, which a spare or interrupted leaf-canopy cannot hurt, a mixed growth may consist of shade-avoiding species.

(2) On very poor soils, such as those on which the *Boswellia thurifera*, &c., thrive, other shade-avoiding species, provided they are sufficiently valuable, such as teak, &c., may be mixed with the former. This mixture is often not only justifiable but also necessary. For instance, in many forests consisting chiefly of *Boswellia*, the teak has no other nurse to protect it against frosts.

V. Individuals of species, which cannot or are not intended to form the prevailing tree in a forest, ought to stand scattered singly, or in small bouquets, and not in large groups, in the midst of the remaining growth. If those species have dense crowns, such groups would hurt with their heavy shade neighbouring trees of other species, without helping them to any appreciable extent in clearing their boles; while if they possess spare crowns, the soil below them must necessarily deteriorate. Besides this, unless the species forming the surrounding growth possessed the same requirements as to light as the trees composing the groups, the stems standing along the edge of those groups would grow unequally, putting on more wood on one side than on another, and would thus be ill-adapted for boards and scantlings of the better descriptions, which would obviously contract and expand in the most irregular manner, and thus be subject to warp very considerably.

Moreover, as has been already shown above, (Advantage IX, p. 112-3) a mixture of several species facilitates the natural regeneration of a forest, so that the existence of pure groups here and there throughout the forest increases the difficulty of its natural regeneration.

Exceptions to this Rule:

(1) When the fertility of the soil varies so that we have well-defined patches of distinctly different degrees of fertility, there is no alternative but to allow each patch to be stocked with the species, be it one or several, best suited to it.

(2) When a shade-avoiding species has to be cultivated side by side with a more rapidly growing and particularly dense-crowned species, there is similarly no alternative.

(3) Certain individuals of a crop are sometimes preserved, when the rest of the crop is felled, in order to allow them to acquire larger dimensions. These must inevitably inflict some injury, by the cover of their crowns, on the succeeding new generation. But the mischief can evidently be minimised by selecting them standing in groups of greater or less extent.

SECTION III.

Characteristics of an auxiliary species.

The meaning of the expression "auxiliary species" has been clearly explained in Chapter I on DEFINITIONS. But after what has been considered in the foregoing sections, we are now in a position to lay down more strictly the full connotation of that term.

An auxiliary species must fulfil the following essential conditions :—

1. *It must become readily marketable as soon as it has reached the pole stage.*—Until this stage of growth has been attained, every individual tree and shrub in a crop, by its struggle for existence with its neighbours, contributes towards the favourable development of that crop. Thenceforth a tree here and a tree there hampers the free growth of, or threatens to suppress, others more valuable than itself and must, therefore, be removed at once. Unless the stems so removed are collectively readily marketable, and their sale-value is at least sufficient to cover cost of felling and export, it is evident that the unproductive nature of the operation in question would, in the majority of instances, prohibit its ever being undertaken at the right moment.

2. *It must be a soil-improver.*—This condition is obvious, if the other species in the crop are shade-avoiding, and, therefore, spare-crowned; and it is equally obvious that, if these latter species are shade-enduring and hence dense-crowned, their auxiliary must also be dense-crowned, and thus necessarily a soil-improver.

3. *As a consequence of the immediately preceding condition, it must also be shade-enduring.*—To be dense-crowned is to be shade-enduring.

4. *It must be able to thrive in the same soil as the principal species.*—This is a truism.

5. *It must possess a different ramification of branches and roots from that of the principal species.* In other words, it ought to be able at once to occupy or fill up space in the soil and in the leaf-canopy, which the principal species cannot profitably utilise; and it must be able to do this without tending to invade and strangle the crowns and root-apparatus of the latter.

6. *Its stature must not be less than the minimum length of bole demanded from the principal species.*—In no other way, save very exceptionally, could this length of bole be produced and the leaf-canopy, at the same time, maintained in a complete state.

7. *If natural regeneration is sought, the auxiliary species should be able to reproduce itself spontaneously and readily by seed from a few seed-bearers only; and if the regeneration is to be effected artificially, its propagation by means of sowing or planting, or both, ought to be easy and inexpensive.*—It stands to reason that as a crop ages, the relative proportion of the principal species ought to increase as much as practicable. Hence we must be able to effect the natural regeneration of the auxiliary species with as few seed-bearers as possible.

8. *Its longevity ought to be at least equal to the term required for the trees of the principal species to attain their full length of bole.*—Otherwise, after the death of the trees of the auxiliary species, none could be produced for years to take their place, and in the meantime the absence of companions to help in drawing them up and in pruning their boles naturally would affect detrimentally the longitudinal growth of the trees of the principal species.

The preceding is a complete enumeration of the *essential* characteristics of an auxiliary species; it remains now briefly to mention the *useful* and *desirable*, although non-essential, characters of the same. They are—

1. *Rate of upward growth, until the high pole stage is reached, somewhat slower than that of the principal species.*—In other words, it is desirable that, provided that the auxiliary species is not required as a nurse, it should at no stage of growth be able to rise up on a level with, much less to overtop, the principal species.

2. *A hardy constitution.*—Young individuals of the auxiliary species should be able to stand a certain appreciable degree of exposure.

3. *Longevity not inferior to the rotation applicable to the principal species.*—This is the best guarantee for successful natural reproduction of the auxiliary species, for the presence of a sufficient number of seed-bearing individuals of it, when the crop comes under regeneration just before being felled, is thereby assured.

4. *Ability to shoot up again readily after repeated cutting back or topping off.*—Many an individual of the principal species has to be saved from suppression by faster growing individuals of the auxiliary class, and this can be done only by keeping these latter down for a time by cutting them back or topping them, as the case may require, once or more frequently.

5. *Persistence of foliage during as many months of the year as possible, combined, of course, with a lower stature (Essential Condition 6), and slower rate of upward growth (Useful and Desirable Character 1).*—This will add to the effectiveness of the auxiliary species as a soil-improver and as a nurse for any advance growth that may come up.

9. *Accommodating nature as regards soil and situation.*—The possession of this quality must materially facilitate the culture of the auxiliary species in the general interests of the entire crop.

BOOK II.

THE CREATION AND REGERENATION OF FORESTS.

CHAPTER I.

PRELIMINARY DEFINITIONS.

1 A SLIP is a severed branch or portion of a branch or stem, that is partially or entirely put into the ground, where it *then* strikes root.

2. A LAYER is also a branch or portion of a branch or stem, which is, however, first placed in contact with soil at some point below the growing extremity, and is not severed from the parent plant until *after* it has taken root.

3. To TRANSPLANT means simply to remove a plant from any one point to any other, and the plant so removed, or taken out of the ground to be so removed, is termed a TRASPLANT.

A transplant may hence be either a seedling, a rooted slip, a layer, sucker or a rhizome with or without its culm.

4. A forest may be created or regenerated either *artificially* or *naturally* (Def. 45, p. 6), or both artificially and naturally. When natural means alone are employed, the resulting crop will be composed of untransplanted seedlings sprung from self-sown seeds or of coppice shoots or of both.

5. When artificial means are resorted to, the propagation is effected either by *direct sowing* or by *planting*.

In DIRECT SOWING, as the term implies, the seed is placed in the ground in the forest itself which is to be created or regenerated, and at the point itself which the seedling is intended finally to occupy.

The meaning of the term "*planting*" is too obvious to require a formal definition. In *planting* we are strictly speaking limited to the use of transplants alone, but the term is also applied to the putting down of unrooted slips.

6. A YEARLING is any plant that is less than two years old.

7. A PLANTATION is, strictly speaking, a forest composed exclusively of transplants, but the term is also commonly used, both in official and foresters' language, to denote a forest raised by *direct sowing*.

This ambiguity, which is very much to be deplored, cannot now be remedied; but, when a distinction is necessary we may employ the term DIRECT SOWING to denote that the plantation in question has been raised from seeds sown *in situ*.

8. A NURSERY is any area specially used for the raising of transplants. A nursery may be maintained or intended to be maintained year after year in a continuous manner, or it may be kept up for a limited number of years until a certain definite and limited amount of planting has been accomplished, when it is abandoned altogether. Nurseries may accordingly be either PERMANENT or TEMPORARY.

9. The term TO LIFT UP will be used to denote the operation of taking a plant out of the ground preliminary to transplanting it.

10. To PRICK OUT a plant is to remove it from wherever it stands, whether in a nursery or not, and put it down again at any point *inside* a nursery; while TO PUT OUT a transplant means to place it in the ground *in the forest* at the point itself which it is finally to occupy. To *prick out* and to *put out* are thus only two special cases of *transplanting*.

11. To UNDERPLANT is to plant *under* an existing taller crop.

12. A SEEDBED is any cultivated portion of a nursery in which plants are raised from seed sown *in situ*. Before transplants are put out, they are often removed from the seedbeds and pricked out in regular lines, such lines being termed NURSERY-LINES.

13. To GRAFT is so to apply a portion of one woody plant (the GRAFT or SCION) to another woody plant (the STOCK) that, as a consequence of the operation, an intimate union between the cambium and the living woody and cortical tissue on each side of the cambium takes place and the scion becomes an organic portion of the stock.

This union is effected by the production of an intermediate connecting parenchymatous tissue between the contiguous surfaces of the stock and the scion.

BUDDING is the special method of grafting, in which the scion consists only of a bud and of a strip of bark in which the bud lies embedded.

CHAPTER II.

NURSERIES.

Whatever method we adopt for the creation or regeneration of a forest deserving of the name, the establishment of a nursery is indispensable. If planting is resorted to, the necessity of a nursery in which to raise the transplants is obvious. However successful natural regeneration may be, however conscientious or skilful the care and precautions taken in executing direct sowings, there will always be spots of less or greater magnitude in which seedlings will die off or refuse to come up, or in which stools will be unproductive, or in which a given valuable species will be absent or insufficiently represented, in which, in short, the early establishment of plants of a certain species and of a given size and vigour will be urgently required. In all these cases a nursery must be at hand from which a supply of such plants is immediately available. In a nursery all the plants receive individual attention, and it is there alone that they can be raised under the most favourable conditions possible for any required purpose. How to establish a nursery is, therefore, the first question that requires to be answered.

Besides this, from the point of view of the student himself it is undoubtedly preferable first of all to study the production and early growth of forest trees under the conditions obtaining in a nursery, where those conditions are completely under our control and may be made as favourable as possible for the purpose in hand, before passing on to the study of their production and early development under the abnormal conditions obtaining in a forest, which conditions it is not in our power to regulate or modify except to a comparatively slight extent.

This being so, we will (1) enquire into the characters which constitute a good transplant, (2) distinguish between permanent and temporary nurseries, (3) formulate general directions with

regard to the collection, storage and testing of seeds, (4) give a short account of the principal manures suitable for forest purposes, and (5) describe how to establish and maintain nurseries of either class.

SECTION I.

Properties of good transplants.

Before we can undertake to establish a nursery we must first of all know, as far as it is possible to do so, what description of planting material to raise, that is to say, what kind of transplant will succeed best in any given case. But as regards the species and the age, size and special quality of the plants required—points of very great moment and often demanding exceptionally accurate perception and judgment—they are completely determined for the nurseryman by the forester working out in the forests, and they will be found discussed in their proper place further on. The nurseryman need only be able to recognise a good transplant by its general appearance, so that he may know what to do in order to raise such plants and how to select those he has to send out.

It is evident that for different kinds of work, different qualities of seedlings are required, qualities depending on the species, age, soil, climate, locality, &c; but there are certain general characters which all planting material must possess, and these combined general characters constitute what may be termed *vigour*. In its normal state every species has at each stage of growth a different habit, *i.e.* a general arrangement and shape of root-apparatus, stem and crown peculiar to itself. This limitation being borne in mind, a vigorous seedling will be recognised by (i) its form and proportionate development approaching the normal habit of the species, (ii) a full root-apparatus, and (iii) a healthy crown.

(i). Form and proportionate development.—The form of of the seedling should approach as nearly as possible the form of the normal seedling of the given species, the development of each part being proportionate to the development of every other part. For instance the stem should not be abnormally thin for the height of the seedling or the fullness of the crown, the crown should not be abnormally small for the thickness of the stem, and so on. Whenever there is any want of just proportion (and this will generally be the case, since the normal state will rarely be attained), it is better that the extent of the roots should predominate over every other part, and the lateral spread of the crown over the height of the plant or the thickness of stem.

(ii) A FULL ROOT-APPARATUS.—This expression is of course a very comparative one. For instance all yearlings agree more or less in possessing chiefly a tap-root with only a few root-fibres. Again, in the case of teak, the expression in question must be taken to mean simply the main tap-root with a few spare rootlets and root-fibres, whereas in other cases it may mean a dense mass of rootlets and root-fibres with a relatively small tap-root; and between these extremes there will be many intermediate degrees. But considering any one species by itself, the more numerous the root-fibres and the rootlets which bear them are, the more vigorous will the plant be. The number of the root-fibres, even if they are not produced uniformly at every point, and the abundance of the little lumps of earth organically attached to them and which prove their activity, are the main points to look to.

(iii) A HEALTHY CROWN.—For any given species a healthy crown is indicated by proportionately numerous vigorous leaves of the proper shade of green, numerous and full buds, and a more or less symmetrical crown of a depth equal in most cases to at least half the height of the seedling. In all the woody portions the liber and cortical parenchyma should be relatively thick, vigorous, full of sap and of a healthy green, and covered over with as little suber as possible. A thick suberous layer on thin or young parts is generally a sign of languishing growth, and a disproportionate thickness of it is usually a first step to the seedling becoming hide-bound.

Seedlings possessing the characters just described are such as develop from good seed in a loose soil full of nourishment, with free room to develop on every side and with no adverse circumstance of any kind to produce any check in their growth. It is evident that in addition to these qualities, which may be termed the qualities of the normal plant belonging to any species in question, the seedlings should also be such as may be planted with ease and with the least possible risk of injury to their different parts or to their general vitality. Hence the smaller the compass of the entire mass of their root-apparatus is, the higher will be the quality of the planting material, as it can then be extracted from the nursery and put out into the forest with greater ease and with less liability to injury. But this character will obviously be subject to modification by the circumstances under which the transplanting has to be done.

In judging of a given lot of planting material the amount of care exercised in examining its quality, and the degree of strictness with which the presence of all the preceding characters is exacted, must necessarily vary with the character of the species, some species recovering from injuries or regaining, after having been kept back, their full vigour more easily than others.

SECTION II.

Permanent and Temporary nurseries compared.

Whether a nursery should in any given case be *permanent* or *temporary* is a question that is determined entirely by considerations of convenience and expense.

The nearer the nursery is to the site where planting is to take place, the better, for the transplants will then suffer less in transport and need not be lifted up until almost the very moment they are wanted, while the cost of carriage may thereby be indefinitely diminished. Temporary nurseries, being, as the name itself implies, intended to last only a few years, one or more can be made in immediate proximity to, or in the very middle of, each planting site of any extent, and abandoned as soon as the work there has been completed, new ones, if necessary, being started further and further away as the planting operations progress onwards. This could not obviously be done in the case of permanent nurseries, except by multiplying their number beyond the limit imposed by the requirements of economy and efficiency.

It is evident that once a nursery is established, it can be maintained indefinitely without any further expenditure on the preparation of the soil, on fencing, and on the supply of means for watering it, except what is necessary for mere repairs and maintenance. This expenditure is always comparatively heavy, and is incurred once for all in a permanent nursery, whereas it constitutes a fresh charge each time a temporary nursery is made. And, indeed, on this account the labour and outlay expended in the latter class of nurseries, on the preparation of the soil and on fencing and irrigation works, are generally kept down as low as possible, with the result that those of the former class yield, on the whole, planting material of much better quality.

This result is also in a great measure due to the possibility, in the case of permanent nurseries, of maintaining a more efficient establishment, of exercising closer and more effective supervision

and control, and of observing, to the desirable extent, that continuity of plan, method and purpose, without which success cannot always be commanded.

Moreover, in consequence of the large scale on which work is carried on and the greater efficiency of the establishment and of the supervision exercised over it, the cost per individual, transplant of equal or even superior quality raised is always very much lower in a permanent nursery.

Another important distinction between the two classes of nurseries lies in the fact that with a permanent nursery, which is always made on a large scale, no inconvenience or delay occurs in meeting all ordinary fluctuations in the demand for transplants, such as are inevitable in the treatment of any forest that is under some sort of systematic management; whereas with a temporary nursery, unless only yearlings are required, a certain time must elapse before a sudden increased demand can be met, while if less than the estimated number of transplants are actually used, the balance is likely to go to pure waste from becoming too old for use at a later period. Hence temporary nurseries answer only for some definite work to be accomplished, as, for example, if so many acres are to be planted up in a given manner within so many years, &c.; they can but seldom, if ever, meet the general wants that arise in the ordinary routine management of an entire forest of any size.

Thus only two advantages remain to the temporary as compared with a permanent nursery, *viz.* (1) reduced cost of transport, and (2) use of the transplants almost as soon as they are lifted up. And consequently, whenever there is any question of establishing that class of nursery, it must first be proved, after it has been ascertained that sufficiently good planting material can be raised thereby, (*a*) that saving on carriage exceeds the increased cost of raising the required number of transplants, and (*b*) that the more assured success, that may be anticipated owing to the minimised exposure of the transplants between their leaving the nursery and being finally put down, is sufficiently real and appreciable to compensate for the extra labour, expense and inconvenience entailed by the establishment of a new nursery or the continual change of nurseries, as the case may be.

The general truth of the remarks made in the foregoing paragraphs of this section is unquestionable; but exceptional cases may occur, in which a temporary nursery may be kept up for a

sufficiently long series of years to justify a large outlay on fencing, irrigation and cultivation of the soil, and on the maintenance of a strong and well-paid, and, therefore, skilful and experienced. establishment; *e. g.* when very heavy planting work is to be executed over a fairly extensive but compact area, such work being immediately followed by a permanent contraction of the artificial regeneration operations due to natural means being more largely employed in the sequel. In cases of this nature a temporary nursery will not yield inferior results to a permanent one, with which, indeed, it will assimilate, in character and the methods of establishment and maintenance, to such an extent as entirely to cease to be a temporary nursery save in the mere name.

Temporary nurseries have their *raison d'être* most often in a country of lofty mountains, where distinct zones of vegetation prevail according to the altitude. Each such zone, implying an entirely different climatic influence from the rest, will generally require a separate nursery for itself, and then as each zone has usually a limited local extension, temporary nurseries will there be rule, permanent nurserses the exception.

SECTION III.

Collection, testing and storage of seed.

This subject will be treated of under four several heads as follow:—

1. Collection,
2. Preliminary manipulation,
3. Testing, and
4. Storage.

ARTICLE 1.

COLLECTION OF SEED.

Seeds may be obtained either (1) by collecting directly, or (2) through contractors, or (3) by purchase in the market, or (4) by exchange. Owing to the backwardness of forest culture in India, the third source scarcely exists for us, and the fourth is almost as limited. This is, however, no great disadvantage, as seeds collected directly or through contractors must necessarily belong to the latest crop, and are more likely to be fertile and sounder than those obtained otherwise; and not only this, but they can be more thoroughly tested.

The best seeds are produced by middle-aged, fully fertile, healthy, vigorous trees, standing not too close together, and growing in a favourable soil and situation. Very young trees usually furnish a large proportion of barren seeds, while very old or weakly trees yield seeds which are not only difficult to keep but also produce weak plants. Deformities in trees are often inherited, as for instance twisted fibre, a squat habit, &c. Twisted fibre can be easily detected in trees possessing a cracked bark or rhytidome, as the cracks follow the twist.

Seeds ought to be collected only when they are completely ripe; such as are not fully ripe when taken off the tree do not possess the germinative faculty in the same degree as those collected when fully ripe, and they, moreover, lose that faculty much sooner. The ripe fruit of some species persist on the trees for a more or less considerable time; *e.g.*, of teak, *Terminalia tomentosa*, *Pterocarpus Marsupium*, sissu, &c. Such fruit one need be in no hurry to harvest. But there are other species, the majority of the seeds of which, with or without the rest of the fruit, are shed as soon as, or soon after, this ripens; *e.g.*, sal, deodar, *Quercus semecarpifolia* and *dilatata*, *Abies Webbiana*, birch, *Lagerstrœmia parviflora*, *Schrebera swietenioides*, *&c.* The collection of such seeds evidenty admits of no delay.

Rainy weather ought, as far as possible, to be avoided for the collection of seed, especially of such as are small, as, for instance, *Anogeissus*, birch, *Adina cordifolia*, *Stephegyne parvifolia*, *&c.*; but this prohibition obviously does not extend to the case of such seeds as are to be sown at once, or, which comes to the same thing, as cannot under any circumstances be preserved, *e.g.*, sal, *Quercus semecarpifolia*, *&c.*

According to the various species and various circumstances seeds have to be collected in different ways. The fruit may (i) be hand-picked off standing trees, or (ii) collected off felled trees, or (iii) be gathered from the ground after they have been shed naturally, or lastly (iv) be broken off with a hook from standing trees.

(i) HAND-PICKING OFF STANDING TREES.—This method is the most costly of the four, but is the only one practicable in the case of small or light fruit that is easily blown away by the wind, *e.g.*, *Pterocarpus Marsupium*, *Ougeinia dalbergioides*, *Anogeissus*, khair, sissu, *Hardwickia*, elms, maples, ash, &c., or of small light seeds that escape from the ripe fruit still hanging on the

tree, *e.g.*, deodar, silver fir, birch, *Schrebera swietenioides*, *Pieris*, *&c.* The seed collector, sack slung over shoulder or round waist, must climb up into the crown of the tree, with or without the help of a ladder, just as he can manage. What he cannot reach directly with his hand, he must draw to within arm's length of himself by means of a hook attached to the end of a light but strong sapling or bamboo of sufficient length. Branches and branchlets break off less easily when drawn upwards than if pulled downwards; hence it is always advisable for the collector to climb up at once to the highest point he can attain and begin by plucking off the fruit hanging at the summit of the tree. The fruit of many species is more or less articulated to the twig which bears it, and thus comes away easily; but that of some species can only be plucked by twisting or otherwise forcibly breaking off the twig. For the latter class of fruit the use of a cutting implement, such as a pruning knife or an ordinary sickle, is to be recommended. Figure 2 represents a convenient implement, which combines a sickle-like hook (*a*) and a sort of gouge-like edge (*b*) in which it terminates. If the fruit cannot, under any circumstances, be reached with the hand, an implement similar to that used by mango-gatherers may be employed (Fig. 3.) The bag (*b*) receives the fruit or seeds, and prevents them from escaping or falling to the ground, while the peculiarshaped opening (*o*) catches the stalk just above the fruit or bunch of fruits and breaks it off. Fig. 4 represents a modified form of the same implement; *s s* are fine sharp saw-edges which cut through the stalk as the man draws the implement towards himself.

(ii) GATHERING OFF FELLED TREES.—Trees that are to be cut for export in the ordinary course of work often yield a considerable supply of good seed. They should be felled or lopped immediately the fruit is ripe. A pruning bill or hook often facilitates very materially the collection of the fruit. This is the only method applicable to the various kinds of bamboos.

(iii). GATHERING FROM THE GROUND.—The seeds that fall first are generally barren or worm-eaten; they should invariably be rejected. To this end the dead leaves and early-fallen fruit or seed should be swept away from under the selected trees. This method of collection is very economical, and is peculiarly suited to large heavy fruit that falls more or less perpendicularly, and does not break up and allow the included seed or seeds to disperse; *e.g.* *Quercus incana*, the sandalwood tree, sal, *Termi-*

nalia Chebula and *belerica*, *&c.* To help the fall of the seed or fruit, the branches of the trees may be shaken.

(iv). PLUCKING OFF THE FRUIT FORCIBLY FROM STANDING TREES.—When trees marked to fall within a year or so are chosen as seed-bearers, it may be found inconvenient or impossible to wait, in order to collect the seeds, until the trees are felled. On account of the nature and small size of the fruit and seed, method (iii) may also be inapplicable, while (i) would be unnecessarily expensive, since there is no reason, in this case, for sparing the fruit-bearing branchlets and twigs. The fruit may then be broken off singly or in bunches with the aid of a strong hook, forming a sharp angle of about 30° and firmly attached to one end of a long sapling or bamboo. The inside edge of the hook should be sharp or serrated and slightly curved inwards. The hook, being passed over the fruit-bearing branchlet or twig at the point at which it is to be broken off, should be jerked downwards; or, if that does not suffice, it should be worked round once or twice so as firmly to catch the branchlet or twig, as the case may be, when a single jerk will suffice to cut the latter through. Where small wood has no value, or there is no objection to thinning out the crowns of the trees, branchlets of a certain thickness may be lopped and the fruit then hand-picked from them. Some trees produce bunches of fruit, the common stalk of which dries up at maturity and easily disarticulates from the rest of the branchlet, the panicled fructification of teak being a good instance in point. The present method may be employed with such trees, both independently and also, when all the fruit, although ripening more or less simultaneously, do not fall together, hand in hand with method (iii).

ARTICLE 2.

PRELIMINARY MANIPULATION OF FRUIT OR SEED.

The fruit or seeds of many trees require to undergo some previous manipulation before the seed is in a fit condition to be sown or stored up. Either (a) the seeds are enclosed in a fleshy pulp, *e.g.*, *Dillenia*, *Schleichera trijuga*, *Artocarpus*, *Gmelina arborea* *Diospyros*, *&c.*; or (b) they are included in a capsule or pod or between scales, *e.g.* *Lagerstrœmia*, *Schrebera*, *Michelia*, khair, *Hardwickia*, babul, *Coniferæ*, *&c.*, or (c) they are surrounded or armed with wings or with hairy appendages, which interfere with their uniform distribution in sowing as well as uselessly increase their bulk and weight, *e.g.* Teak, some *Terminalias*, *Pterocarpus*

Marsupium, elms, maples, pines, firs, poplars, willows, &c. ; or (d) they are so full of moisture that they cannot be stored up at once without heating and fermenting, *e.g.* pines and firs, *Anogeissus, Quercus incana &c.* ; or (e), although as ripe as they can ever become on the parent tree, they would germinate badly or after much delay if sown as soon as collected, *e.g.*, teak, *Terminalia tomentosa* and *Arjuna, Pterocarpus Marsupium*, babul, ash, &c.

(*a*). SEEDS ENCLOSED IN A FLESHY PULP.—In many cases the pulp may be got rid of by allowing it to rot, with the fruit collected in heaps, and then washing it off in large vats with abundance of water, the contents of the vats being well worked about with strong rods bound together broom-fashion. Edible fruit, such as that of *Zizyphus, Diospyros, Buchanania, Schleichera, &c.*, give no trouble ; people who live in, or close to, the forest will bring in all the seed required in return merely for the privilege of collecting the fruit, with occasionally a trifling money remuneration added. Some kinds of fruit may also be given to goats and cattle, which eject the seed when chewing the cud, *e.g. Zizyphus, Terminalia belerica* and *Chebula, Phyllanthus Emblica, Gmelina arborea, Prosopis spicigera, &c.*

(*b*). SEEDS INCLUDED IN A CAPSULE OR POD, OR BETWEEN SCALES.—The quickest method, when that is practicable, is the application of heat, under action of which the valves of the capsules or pods and the scales of the cones open out or disarticulate, and set free the enclosed seeds. In many cases simple exposure to the sun suffices; in others, however, a higher and more sustained temperature is required, and then special drying-houses are necessary, in which the fruit to be treated is exposed to the direct action of air heated by steam pipes or over an open fire, and kept at the required temperature with the aid of thermometers. The coverings and scales are separated from the seed by raking or ridding or winnowing, according to circumstances. But the application of heat does not suffice for, or may even not succeed at all, with the fruit of many species, *e. g.* sissu, *Hardwickia*, babul, khair, &c. In that case, if the seed is tough enough, threshing in sacs or in the open air, or treading with bullocks on a well-beaten level floor in the manner of the Indian agriculturist will give good results. Some seeds, however, principally those of leguminous plants, do not stand such rough treatment, *viz.*, *Harwickia binata*, sissu, &c., and, in the very rare event of the separation of such seed from its covering being deemed

necessary, the only way to free them, as far as I know, would be to manipulate each fruit individually with the hand.

(*c*). SEEDS WITH WINGS OR HAIRY APPENDAGES.—THE wholesale removal of these appendages, except one by one with the hand, is not always possible without injury to the germinative power of the seeds; but whenever practicable, it should be effected. If the seed is hard or tough, friction, more or less rough, suffices to detach the appendages in question. When this is the case, a very expeditious method would be to loosely fill up large stout sacs with the seed, and to thresh these or work them violently backwards and forwards, according to the toughness of the seeds, until the appendages were detached or crushed, when they could be easily separated by the ordinary process of winnowing. Treading with cattle may sometimes be found efficacious. Threshing is necessary for seeds of *Terminalia tomentosa* and *Arjuna*, *Pterocarpus Marsupium*, &c. Treading with cattle or friction in sacs will succeed perfectly with teak, &c. With brittle or otherwise delicate seeds the following process may often be employed with the best results:—They should be spread out and sprinkled over lightly with water from a pot with a fine rose, and thus moistened they should be collected into large heaps. As soon as a gentle heat is felt on inserting the hand into a heap, the seeds should be spread out to dry. When they are again dry, the appendages will be found to have disarticulated of themselves.

(*d*). SEEDS TOO MOIST TO BE STORED UP AT ONCE.—The seeds of many species have, in order to anticipate their natural dissemination and complete dispersion, to be plucked from the parent tree before they are quite dry. Other kinds of seed again contain a great deal of moisture even when they fall off naturally. Such seeds should be spread out, not more than from 2 to 3 inches high, in a dry, airy, sunny place, and turned over with a rake twice or thrice daily for a period varying with the kind of seed and the dryness and temperature of the weather. After this they should be piled up higher, the raking being continued as before, but being limited to only once a day. This latter process should go on until the seeds are sufficiently dry to be stored or packed up. Experience alone can tell when this is the case. It is needless to say that in the cold weather the seeds should be removed under shelter while dew is being deposited. As regards seeds that are moist even when they are shed naturally, this drying is

really the completion of the ripening ocess, for such seeds germinate more promptly when they have been thus dried than if sown as soon as they fall off from the parent tree.

(*e*). SEEDS THAT REQUIRE A FURTHER PROCESS OF RIPENING AFTER FALLING OFF FROM THE PARENT TREE.—Among agricultural crops our gram is a well-known instance of such seeds: it will germinate freely only several months after it has been harvested. Instances of forest seeds, already given higher up, are those of teak in Central India and Bombay, of *Terminalia tomentosa* and *Arjuna*, of *Pterocarpus Marsupium*, babul, ash, &c. Drying increases the germinative facutly of each one of these species, especially the power of swelling up enjoyed by the embryo, and by the perisperm when there is one, with imbibed water. In the case of teak in Central India, it would appear, from numerous experiments made, that continued exposure to all the alternations of the weather during a whole year, provided fermentation is prevented, favours this second ripening process.

ARTICLE 2.

TESTING OF SEEDS.

There are three practical ways of testing the germinating power of seeds; they may be termed respectively (a) the ocular (b) the weight and (c) the germination tests.

A. The Ocular Test.

This method of test, as the name implies, consists in the examination of the seeds with the eye, assisted, if necessary, with an ordinary magnifying lens. If the seed is sufficiently large, it is cut in two with a sharp knife and the section is then examined. The germ, including the perisperm (when there is any) should, if thoroughly sound, fill the testa completely, possess the healthy colour peculiar to the ripe seed of the species in question, emit no unpleasant odour and contain a sufficient amount of moisture. Next, the testa should be removed in order to assure oneself of the soundness of the plumule and radicle. The size of the seed is no criterion of its germinating power, but the larger seed generally produces the hardier and more vigorous seedling.

When the seeds are too small to be cut open easily, unless they are oily, we have no proof of their soundess beyond the absence of any unpleasant odour and the healthy appearance of the outside of the testa. If they are oily, the presence of the oil is ascertained

by crushing them on a hard surface with the nail of the thumb or, if very unyielding. with a hammer-head. A spot of oil or grease on the nail or hammer-head will be a certain sign that they are good, for in seeds that are at all decomposed, the oil will have disappeared, having been oxidized and converted into other substances. Sometimes small seeds are tested for moisture by placing them on a red-hot iron plate. If the seeds burst with a slight explosion, due to the sudden formation of steam, it is a proof that they contain a sufficient amount of moisture.

The ocular examination of seeds requires great experience and special knowledge, and even then there is no slight risk of error, particularly in the case of small seeds. It ought never, if we can help it, to be employed by itself as a final test in the purchase or taking over of a large quantity of seed, and its use should, as a rule, be confined to the preliminary examination of a given lot of seed, so that the useless labour of subjecting really bad seed to the more rigorous, but generally tedious, germination test may thereby be avoided.

It is superfluous to add that when the quantity of seed to be tested is very large, it should be divided, without any selection, into smaller lots and each lot should be tested separately. Indeed, this remark applies also to the two following tests.

B. The Weight Test.

In this test a sufficiently large measure or number of seeds is weighed and their average weight compared with the previously ascertained standard weight of good seed. This is a very uncertain method, for in the first place seeds of one and the same species will have a different average weight in different localities; in the second place, seeds may lose an appreciable part of their natural moisture, and hence also weight, without their germinative power being at all impaired thereby; and, in the third place, the dealer or contractor might moisten the seed just before the test. In any case, it ought never to be employed alone, but merely as an adjunct or auxiliary to the preceding or following method.

C. The Germination Test.

In this system a given number of seeds taken without selection from a lot to be tested, is placed under the most favourable conditions for rapid germination, and then the proportion of seeds that actually germinate, combined with the average time which they have taken to germinate, indicates the quality of the entire lot.

The quality will be *directly* as the proportion germinating and *inversely* as the number of days taken in germinating; so that, expressed in figures, it may be represented by a fraction the numerator of which is the percentage of successful seeds and the denominator the average number of days taken by each successful seed to germinate. The number of seeds tested must, of course, be sufficiently large to guarantee the trustworthiness of the results, and, if the lot to be tested is at all considerable, a few seeds should be taken here and there from various points. It is obviously most convenient to experiment with 100 seeds or some multiple of 100. It is unnecessary to wait until the entire process of germination is over in order to consider the test complete; the germinative power of the seed is sufficiently proved if the germ has swelled up, the plumule and radicle have already attained a certain development, and the cotyledons, and the perisperm, if any, are perfectly healthy. The water used should, if possible, be soft, such as rain or snow or distilled water, or it may be taken from a small running stream that does not flow over limestone rocks. It is evident that the progress of any experiments undertaken should be watched from day to day.

In favourable weather the seeds may be sown out in the garden in ordinary soil; or, if they are small and difficult to find again, they may be enclosed in a fold of flannel or any absorbent cloth before being put into the soil, by which means they could be examined from time to time and the progress of germination constantly watched. Enclosing the seeds in the flannel or other absorbent cloth has also some other important advantages: the seeds are less likely to rot from excessive damp, or suffer from insufficient aëration or from rapid alternations of heat and cold, or be attacked by insects, than if they were in direct contact with the soil. An improvement on the preceding method is to sow in ordinary garden pots, which, being portable, can be moved so as always to secure for the seeds the best conditions for germination. Moreover, sown in pots, the seeds are much less liable to be injured by excessive damp. Some special precautions should be employed in the use of the garden pot system. After placing a potsherd over the hole at the bottom, the pot should be half-filled with coarse sand or potsherds or tiles broken up small, in order that no water may collect and stagnate at the bottom of the pot. Good garden soil should then be put in and the

seeds sown in it to the proper depth, which will vary directly with the size of the seed. Instead of watering from above and causing an impermeable crust of fine mud to form on the surface of the soil, the pot may, whenever necessary, be placed for a sufficient time inside another larger pot containing water, which would then penetrate to the soil former by capillarity through its sides, but principally by way of the hole in the bottom through the layer of coarse sand or broken tiles below.

For soil may be substituted sawdust, pounded charcoal or coke, or brick-dust, especially if the seeds are small or are likely to be clogged over too thickly with mud. All four substances are highly absorbent, keep moist easily, admit air freely and yield up slowly, but with sufficient rapidity for the requirements of germination, the water they contain.

There is, however, no necessity in every case for burying the seed at all. Some seeds, such as bamboo and many leguminous kinds, germinate easily and rapidly enough if simply kept in a warm place in a shallow dish of water. Others sprout, if enclosed in a roll of some loose-woven woollen cloth, such as flannel, that is constantly kept moist. The best way to keep the cloth moist, without allowing it to become too wet, is to connect it by means of a sufficiently thick skein of wool or worsted with water standing at a lower level than itself, which would then ascend by capillarity. If, owing to rapid evaporation, especially in a dry atmosphere, the woollen cloth is likely to cool down to too low a temperature, it may be put under a globe of glass or metal, and, if necessary, exposed thus to the sun or before a fire. But a still better plan (see Fig. 5) is to use a wide-mouthed glass bottle which is kept partly filled with water. One end of the skein being hooked on to the mouth of the bottle, the other should hang down in the water as far as the bottom itself, while the roll of woollen cloth containing the seeds is attached to the skein above the level of the water. In order to check evaporation and the consequent refrigeration, a perforated cork or wooden stopper or tin-cap should close the mouth of the bottle. The water can be replenished whenever necessary. The bottle, with its skein, stopper and roll of woollen cloth, thus forms an easily-portable apparatus, which can be exposed to the sun or before a fire, or kept in a warm place, just as is required, and may be carried about in camp without interfering with the trustworthiness of the test. The glass jars

with screw tin-caps, in which prunes, are imported to India, will serve our purpose excellently.

Various special apparatus have been constructed for procuring the germination of seeds under the most favourable conditions irrespective of the season of the year. Two of these may be here described.

HANNEMANN'S GERMINATION PLATTER (Figure 6).—This is a circular plate of porous earthenware about six inches in diameter and two inches thick. On the upper side are numerous circular hollows numbered consecutively, and about 3/8 inch across and 3/16 inch deep. The underside bears eight radial furrows about 1/5 inch wide and 3/25 inch deep, which facilitate the passage of water through the earthenware, from the under to the upper surface. In order to use the platter, it is first soaked in water for about 24 hours and then placed in a flat dish containing enough water to just reach its upper edge without flooding it. The seeds are then placed singly in the hollows, and either left uncovered or covered over with flannel or good soil. The water should be replenished whenever necessary.

NOBBE'S APPARATUS (Figure 7).—This consists of a square-shaped block of porous earthenware of about eight inches side and two inches thick and with only the under surface and sides glazed. On the upper side is a hollow, like a shallow bowl, surrounded by a canal which goes almost through the thickness of the block and is intended to hold water. The seeds are placed in the bowl and are kept constantly moist by the water which finds its way to them from the surrounding canal through the porous earthenware. To keep out external influences, the apparatus is protected with a cover (*c* in figure), which is raised at the corners to allow a free circulation of air, and is perforated in the centre to admit a thermometer in case of delicate experiments.

Experiments carried out by Baur prove that all the various methods of test by germination yield more or less the same results, although, on the whole, sowing in a garden bed is the least to be relied on, while Nobbe's apparatus is the safest.

The germination test is the best of all, as it is the most certain of the three and by it alone can the exact proportion of good seed and the germinative power of such seed be accurately gauged But it is evident that it can be employed only with seeds that can be forced to germinate within a reasonable time; otherwise

the test may be vitiated by unavoidable accidents during the long interval between the commencement and close of an experiment. Moreover, there are some seeds, like those of teak and babul in many parts of India, an entire lot of which, all collected at one and the same time and from one and the same tree, never germinate together but at intervals of weeks, months and even one and two years. For such seeds the germination test alone would necessarily be insufficient and in most cases impracticable, but, whenever practicable, it should always be adopted in combination with the ocular method.

ARTICLE 3.

STORAGE OF SEEDS.

Some seeds cannot be preserved: they must be sown at once. Those kinds which ripen during the rains, such as sal, *Quercus semecarpifolia, Mesua ferrea*, &c. cannot, from their nature, keep. The seed of the first two species, particularly the oak, often germinates on the parent tree before being shed. Seeds which contain a large quantity of oil are, as a rule, very difficult to preserve, as the oil soon decomposes, *e. g.*, the various species of *Bassia* and *Artocarpus*, Cashew-nut, deodar, the pines, especially *Pinus Gerardiana*, &c. So also seeds containing a large quantity of moisture and enclosed in a thin soft shell generally keep badly, as, for instance, the various species of *Eugenia* and elm, sandal, acorns, &c. Usually seeds retain their vitality longer if allowed to remain in their fruit-coverings. Some seeds keep for a number of years with no further precaution than merely protecting them from continuous damp; of this class teak is the most remarkable example.

Steeping seeds in a solution of alkaline borates and silicates and then drying them checks their germination without in any way injuring their vitality.

In storing seeds they must be preserved against germination decomposition, completely drying and shrivelling up, fungi and animals. To prevent germination it is sufficient to withhold one of the three essential conditions for its occurrence, *viz.*, heat, oxygen and moisture. The simultaneous presence of these same three factors is also necessary for decomposition and fungoid growth. Hence in keeping seed it is sufficient to protect it from (*a*) animals and from any one of the following three influences:—(*b*) damp, (*c*) heat and (*d*) air.

A. Protection against Animals.

The animals which attack stored seed are rats, mice, squirrels and insects.

Rats, mice and squirrels can be easily kept out by putting the seed into strong jars; or into metal-lined boxes; or into receptacles placed on supports fenced round with pods of the *Mucuna pruriti* or with sharp spikes (barbed, if possible) or with a smooth surface projecting in every direction horizontally like a disc or obliquely downwards like a quoit or bell. The supports in question may also be surrounded with a sort of masonry moat possessing smooth sides and half-filled with water, the section of the moat being pear-shaped so that animals falling into the water cannot crawl out. Pounded glass, dry sand, ashes, chopped straw, spices or aromatic leaves may be mixed with the seeds, but this plan will succeed chiefly with small seeds.

Against insects storing jars, with every opening stopped up may be used, but the easiest and least objectionable plan is to mix with the seeds bitter leaves, such as those of nim, bakain, *Vitex Negundo*, &c. or some powerful-smelling drug such as asafœtida, camphor, &c. or fine slaked-lime; or a double receptacle may be used, one fitting loosely inside the other and holding the seeds, the interval between the two being filled with unslaked lime.

B. Protection against Damp.

Of all causes of destruction of seed damp is the most dangerous, as it is also the most difficult to guard against.

Seeds with a hard pericarp or testa, like teak, *Zizyphus*, *Terminalia Chebula* &c. have little to fear from damp, if they are ketp on a dry floor in a well-aired place and not piled up too high. A raised boarded floor, with the air playing freely underneath is the most suitable. The seeds may also be kept in stout sacks suspended from the ceiling, or they may be stored in large baskets supported on wooden trestles (Fig. 8). In addition to any one of the preceding methods, the seed may be spread out and turned from time to time.

Seeds that have little moisture of their own may be kept in large jars of burnt or unburnt clay with an opening at the bottom, by means of which they may be taken out as required, and which may be stopped with a wooden plug. But a less expensive method is to plaster the large baskets represented in Fig. 8 with mud and cowdung outside. Wooden chests lined with perforated tin, as described higher up, may also answer.

But when the seeds are easily liable to suffer from damp, more elaborate arrangements must be adopted. The double chest or basket, with the interval between the two chests or baskets filled with lime, should yield good results, as the lime, being an energetic absorbent of moisture, would not allow any to pass in from without. Instead of the lime, husks or clean chopped straw, or nim and other bitter leaves might be used. If the baskets are deep, the seeds might be *stratified* in layers between alternate layers of husks, straw, &c. This plan may be enlarged upon by constructing a circular shed (Fig. 9), with stout wattling, plastered over or not, for walls, and a thatched conical roof supported on a centre-post. The shed should be erected on a solid masonry plinth raised on a substratum of wood ashes to keep out white ants, and surrounded on all sides by a canal possessing a pear-shaped section as described higher up under *A*. The figure shows in section the arrangement of the substratum (a), plinth (b), canal (c), walls (d), roof (e), centre-post (f), and the disposition of the seeds (g) and surrounding lining of straw leaves, &c. (h).

C. Protection against Heat.

If the temperature can be constantly maintained below the point at which germination begins, seeds may be kept damp without suffering any injury. A high temperature is most to be eared for oily seeds, as the oil, which is present as food for the uture plant before it is able to assimilate for itself, is easily decomposed by heat and thus converted into substances of no use whatsoever in germination. To preserve seeds against heat they may be kept in water-tight cases at the bottom of a well or stored in cool underground cellars, which, in most parts of India, with our powerful sun and a prolonged hot weather, must obviously be at a considerable depth.

A common plan followed for the preservation of pulse, cereals, &c., in many parts of India, where the soil is clayey, is to excavate a large, deep pit in raised ground and to plaster the inside with fine clay and cow-dung in order to make it completely water-tight. The bottom and sides of the pit are lined with a thick layer of leaves (nim, *Diospyros Melanoxylon*, *Vitex Negundo*, &c.) or husks or crushed straw, which, besides keeping out white ants, absorb any damp that may come through. The seeds are interstratified with straw, husks or leaves almost up to the mouth of the pit, which is then stopped up, first with straw and leaves, and then with clay

two or three feet thick. The thick loose lining of straw and leaves is an effective non-conductor of heat and thus prevents wide and sudden fluctuations of temperature, besides leaving no entrance for insects, rats and mice. This plan may be adopted with advantage in the case of seeds of species that seed at more or less wide intervals, as, for instance, all the bamboos, *Hardwickia binata*, &c. The cold weather is obviously the best time of the year for this method of storing, when the air is cool and dry.

D. Protection from Air.

As has been already said, damp is most to be avoided for seeds and the best protection against it, especially for such seeds as contain a notable quantity of moisture of their own, is the free play of air round about them. Hence in most cases the admission of air is an indispensable necessity and it is seldom that we are called upon to withdraw seeds from its influence, and then too only when it is a vehicle for moisture. The large pit system described in the preceding paragraph obviously keeps out air most effectually; and indeed, in a general manner, we may say that whatever method is successful in keeping out heat may also be adopted for keeping out air.

E. General Remarks.

It will have been observed that in storing seeds several methods may be adopted to protect them from any single one of the causes of injury or destruction to which they are subject. The final choice between those various methods will of course depend on the circumstances of each case, that is to say, on the nature of the seeds, on the number, nature and destructiveness of the effective causes in question, on the cost and abundance of the seed and on the time up to which the given lot must be kept before being used.

SECTION IV.

Manures.

Before we can sow or transplant, we must render the soil, if it is not already so, as suitable as we can for the purpose. In addition to tilling it, whereby we loosen the soil to a sufficient depth and expose it to fertilising weather influences, we may have to improve still further both its physical properties and its chemical composition. This improvement is effected by the addition of

manures. We accordingly, describe below, in a brief manner, the manures most commonly used by the forest nurseryman.

Manuring may be necessary for one or both of two distinct objects: (1) to modify the physical characters of the soil, and (2) to supply certain elements of plant-food which the soil does not originally contain or contains in too slight a proportion, or to restore to it those elements which have been removed from it by the plants raised therein. A nursery is rarely started any where but in virgin forest land that has been fertilized by generations of tree-growth; but it is seldom that such land possesses uniformly all the requisite physical characters, and even as regards the elements of plant-food, there is nearly always advantage in adding, howsoever little it may be, to what is already present in the soil. Hence, as a rule, in preparing soil for the first time we have to put into it manures which chiefly modify and improve its physical characters, and only secondarily increase its nourishing power for plant-growth.

On the other hand, in a nursery that is already in working order, the physical characters of the soil have been already more or less permanently modified in accordance with all requirements, whereas, howsoever great the proportion of the elements of plant-food may be which we give to the soil in the shape of manures, those elements are constantly being exhausted by the planting material raised therein. The soil of a nursery exhausts itself just as rapidly as soil under wheat cultivation: on the whole, it loses less phosphoric acid but much more potash and lime than the latter. Nursery seedlings only a year old take up from the soil in a single year six times as much phosphoric acid, seven times as much potash and nearly twice as much lime and magnesia as trees of the same species about eighty years old remove from it annually; and whereas these large trees return to the soil, in their fallen leaves and small twigs, almost more than what they have taken up through their roots, the seedlings are carried away bodily, and consequently whatever they may have got from the soil is lost to it for ever. Hence in a nursery that is already in full working order, we must put into the soil manures that affect little, or not at all, its physical characters, but supply to it in a very large measure the direct elements of plant-food.

Thus, according as we require chiefly to modify the physical qualities of the soil or to supply it with useful compounds of nitrogen and phosphorus, and of potash, lime and magnesia,

we have, for the purposes of a forest nursery, two broad classes of manures, which we may designate respectively (*a*) WEAK MANURES and (*b*) STRONG MANURES.

ARTICLE 1.

WEAK MANURES.

The most commonly available weak manures are (1) clay, (2) lime, (3) marls (4) fine sand, (5) wood-ash, (6) charcoal, (7) surkhi-ash, (8) vegetable mould and (9) weak composts.

1. CLAYS.—Under this head we may include also loams and the ooze and crust of fine earth found at the bottom of tanks and stagnant pools. These and the true clays correct the want of consistence and hygroscopicity of sandy soils and render them cooler.

2. LIME.—Quicklime, used as a top-dressing, is applied with great advantage to new soils containing a large quantity of undecomposed or only partially decomposed organic substances, which it rapidly reduces, thereby forming carbonic acid, ammonia, phosphates, and other useful compounds. Such are peaty ground and recently broken up grass-land, besides soils that have been for a long time treated with farmyard manure and vegetable mould. Lime acts beneficially on the soil also by decomposing inert compounds of soda and potash, which it thus releases for the use of plants. Lastly, besides being itself an important element of plant food, it loosens the texture of stiff clays and gives a certain amount of cohesion to loose sands.

3. MARLS.—These have the same physical effect as the clays, except that they produce warmer soils. Containing a large quantity of lime, they exert, to a considerable extent, the same beneficial influences as lime.

4. FINE SAND.—This is added to a stiff clayey soil to diminish its compactness and to increase its capacity for heat. Silt is the best adapted for the purpose on account of the smallness of the grains of sand of which it is composed, and also because it generally contains some nutritive organic and mineral matters. Calcareous sand is obviously preferable to a purely silicious sand.

5. WOOD-ASH.—Wood-ash forms an excellent manure, containing as it does a very large proportion of potash and soda and a considerable quantity of phosphates and sulphates. But it is too expensive a manure to be used separately, and it is, therefore, mixed with farmyard manure, vegetable mould, &c., and is one of the constituents of surkhi-ash (No. 7).

6. CHARCOAL.—This, like wood-ash, can only constitute an auxiliary manure. Its high manurial value is almost entirely due to the remarkable avidity with which it absorbs ammonia, carbonic acid and other gases, and the equal facility with which it gives them up to the roots of plants, and to its rendering stiff and cold soils friable and warm, and dry and porous soils hygroscopic.

7. SURKHI-ASH.—As the name imports, this substance is a mixture of burnt earth and a large proportion of vegetable ash and charcoal dust. The ordinary mixed ash and dust of a brick, tile or charcoal kiln may be used; but, whenever possible, the manure should be specially prepared. On land covered with rich herbage the surface soil, with the roots of grasses and other plants that traverse it, should be cut up, while still moist, in brick-shaped sods (Fig. 10) and dried in the sun. The best soil for the purpose is loam, the poorest are sandy soils. Stiff clays, especially if they are ferruginous, are easily liable to be burnt too hard. When the sods are dry, they should be piled up in small kilns about a yard in diameter and two feet high, and the kilns should then be fired in dry weather. The arrangement of the kilns is shewn in Fig. 11. *a* is a mass of small wood over which two layers of the sods are built up in the form of a dome *b*. Over this is laid a layer of small wood *c*, and over this again two layers of sods *d* and so on. In building up the kiln a passage *m.m.* is left on a level with the ground, whereby the kiln is fired. Obviously the sods should be arranged with their upper grassy surface inside. As the combustion progresses and the small wood gets consumed, the entire mass subsides, producing vents here and there which should be at once filled up and covered over with fresh sods. In doing this more sods are often used up than in the first building up of the kiln. The completion of the burning may require several days. When the kiln has cooled down sufficiently to be handled, the sods should be taken out and broken up fine, an operation that is more easily effected before they have become quite cold. The surkhi-ash should be at once collected in heaps and put under shelter. The advantages of using surkhi-ash are two-fold. Besides increasing the consistency of a too free, and diminishing the compactness of a too stiff, soil, it renders immediately available to the roots of plants, in a soluble form, the mineral matters present both in the small wood, leaves, roots and other vegetable refuse burnt and in the soil itself of the sods; but its effectiveness in this latter respect is gradually lost, however carefully it may be stored up.

8. VEGETABLE MOULD. Vegetable mould is simply thoroughly and slowly decomposed vegetable detritus. Under favourable conditions, the leaves, small twigs, flowers and fruit that fall in a forest decompose and form vegetable mould. In India, however, especially outside the evergreen forests, the conditions are adverse to the spontaneous formation of vegetable mould. In deciduous forests the leaves and other vegetable framents, as soon as they fall, are exposed for a more or less prolonged period to a scorching sun, which, if fire has not already destroyed them, dries up every particle of moisture in them and renders them extremely brittle. Then follow several months of heavy rain, which soaks the leaves to such an extent as almost to make them undergo a process of maceration, the result being that nearly all the useful elements are washed away, leaving behind only the bare fibres which, brittle as they have been rendered by the preceding hot weather, crumble to pieces and are thus in their turn for the most part carried away by the heavy surface drainage into the streams. But even where vegetable mould does form naturally, it is of an inferior description; occasionally it is acid or only partially decomposed, and it is always poor in nitrogenous elements, since the leaves, before they are shed, have given up all their nitrogenous matter to the parts that are still in full growth or which serve as storehouses of nourishment. Hence we must always prepare vegetable mould specially.

In a shady place just outside or in one corner of the nursery rectangular pits, not more than three feet deep, should be dug. But if, as in places in the hills, the temperature of the air is never sufficiently high to promote decomposition, the pits should be dug in an open place on a sunny aspect. If necessary, the bottom and sides of the pits should be carefully puddled to prevent soluble substances from passing into the soil and being thus lost. A pakka masonry linnig would of course be very desirable, if it could be afforded. Into the pits, besides dry leaves, also green, herbaceous plant-parts should be thrown in, succulent portions being the best. Care must be taken that no seeds get into the pits, as the seeds of many weeds, particularly of grasses, often retain their vitality throughout the whole rotting process to which the contents of the pits are subjected, and it is, therefore, advisable to cut all the weeds, that are thrown in, before their seeds have ripened. With the leaves may also be put in some cattle droppings, saw-dust, ashes, a little quicklime, &c. The contents of the pits should always be kept thoroughly saturated, but never

allowed to become too watery, otherwise air could not penetrate all through the mass and decomposition would on that account be retarded. The pits should hence be protected from rain. For wattering the pits slops are better than clean water, and liquid manure is obviously the best of all. From time to time, say once every month, the contents should be well turned with a pole, in order to allow every portion to be sufficiently oxygenated; and it is to facilitate this that the pits should not be deeper than three feet. At the end of the second or third year the decomposition will be complete and the vegetable mould fit for use. When this stage of decomposition is reached, all trace of organised structure has disappeared. It is superfluous to add that a pit should be filled up in a single operation and that no fresh leaves and plants should be thrown in from time to time afterwards: every portion of the contents of the pit should decompose simultaneously and uniformly.

The leaves of some plants decompose sooner or yield a richer manure than others. Such plants should be preferred. In each locality experience will soon show which are the best plants to use. In a general way it may be said that the suitability of the leaves and other plant-parts is in inverse ratio to the quantity of fibres they contain and in direct ratio to their succulence.

9. WEAK COMPOSTS. Composts are simply mixtures, in various proportions, of strong manures or weak organic manures with earthy matter. They are weak or strong manures according as the proportion of the last is large or small. The earthy matters are introduced not only to modifiy the physical characters of the soil, but also to temper the otherwise too energetic action of the strong manures. Composts, into the manufacture of which vegetable mould enters, may be prepared at once in the rotting pits, by throwing in with the leaves, &c. or at any time afterwards, clay or loam or marl; the repeated stirring up of the contents mixes together the earth and organic elements intimately. Perhaps the best and most economical compost is a mixture of vegetable mould and farmyard manure with loam. The addition of a sufficient quantity of cattle droppings, when the leaves, &c. are thrown in, produces this compost. Street sweepings are a kind of compost.

ARTICLE 2.

STRONG MANURES.

The best known strong manures are (1) farmyard manure, (2) poudrette, (3) bone-dust (4) guano, (5) saltpetre, (6) urine,

(7) blood, and (8) strong composts. The fourth and fifth are however too expensive in India to be used by the forest nurseryman. Accordingly only the first three and the sixth, seventh and eighth, which will be numbered respectively 4, 5 and 6, will be described.

1. FARMYARD MANURE.—This is the most generally used of all manures in India and is also the easiest of all to prepare. It is obtained by simply rotting the droppings of sheep, goats and cattle. These droppings could not be used fresh, as not only would their inevitable subsequent decomposition heat and injure the roots of the seedlings, and the seeds they contain cover the soil with grass and weeds, but they would encourage fungoid growth and invite destructive insects, especially the grubs of cockchafers and dung beetles. As regards the relative value of the droppings of the various animals, those of ruminants are to be preferred, because the ruminants, as they chew the cud, masticate their food more completely and pass out the fibrous portions in a finer condition. Amongst ruminants the droppings of cows and goats are preferable to those of buffaloes and sheep; not that buffalo droppings are inferior in nutritive power, but because they feed more coarsely and hence pass their food through in a less well triturated condition, owing to which circumstance their manure attracts white ants. The droppings of sheep are inferior to those of goats, as they generally feed on less concentrated food. Horse dung, owing to the special nature of the food given to that class of stock, is very rich in nitrogenous matter and phosphates, but the mastication of the animal is so imperfect, that much of the food passes out either undigested or in large coarse particles, thus attracting white ants. Where, however, there are no white ants, the droppings of well-fed horses should be preferred to those of cows for a stiff cold soil, in order to give it a freer texture and greater capacity for absorbing and retaining heat; and if the ground is not to be used at once, the manure in question may be worked into the soil before it is fully decomposed, so as to turn its mechanical action to the best advantage and also to check the excessive fermentation to which horse dung is liable, and to minimise the risk of losing a considerable portion of the rapidly forming ammonia. Camel dung makes the strongest manure of all owing to the succulent and herbaceous plant-parts that the animal feeds on.

Whatever the droppings used, they must be rotted in pits similar to those used for preparing vegetable mould; but the necessity for

protection from the sun is not so great here, as the droppings consist of matter that has already undergone a considerable degree of decomposition. Great care should, however, be taken to prevent a too violent fermentation, to which all animal dejections are particularly liable. The contents of the pits should always be kept moist and turned over from time to time, and the manure is ready at the end of two years. During the rotting, ammonia and other useful gases are formed in abundance, and are apt to disappear unless special precautions are taken. The best plan is to sprinkle charcoal dust or finely sifted clay or gypsum thickly over the fermenting heap each time it has been turned up.

Farmyard manure contains from six to seven times as much nitrogenous matter as vegetable mould on an average *i.e.*, from 1 to 2⅓ per cent of its dry weight of nitrogen. Ordinary arable land requires, in order to be fully manured, from 280 to 450 maunds of farmyard manure per acre.

2. POUDRETTE.—Poudrette is the deodorized mixture of night soil with earthy matters. It is extremely rich in nitrogenous substances and phosphates, and should, therefore, never be used pure but combined with vegetable mould in the proportion necessary to secure from five to six per cent. of nitrogen in the mixture. Poudrette may be prepared in pits in the same manner as farmyard manure; but as the offensiveness of the contents prevents its being turned for free aëration, the night soil with the earthy matters should be thrown in in thin layers at a time. It is ready for use at the end of a year. Poudrette prepared with a large admixture of ashes and charcoal dust is the most valuable of all.

3. BONE DUST.—Where a large proportion of phosphates is required, bone dust should be added to other manures, particularly to vegetable mould or surkhi-ash, at the rate of from eight to fourteen maunds per acre. Fresh or unboiled bones are of course to be preferred to boiled ones, which, nevertheless, contain more than 50 per cent. of phosphate of lime.

4. URINE.—Urine is a very powerful manure, and human urine is the richest of all, containing, as it does, more than 30 per cent of urea or nearly 8 times as much again as that of the cow and more than 4 times as much again as that of the horse Urine should never be used except after putrefaction, and then too, largely diluted with water or mixed with earthy matters, as in an unmixed state it would be very injurious to plants.

During the putrefaction a large amount of ammonia is formed and must be fixed by the addition of gypsum, whereby the volatile carbonate of ammonia is converted into the non-volatile sulphate.

6. BLOOD.—Blood is a very powerful manure, not only on account of its nitrogen (nearly 16 per cent.) but also of the numerous useful salts it contains, chief among them, after common salt, being phosphates. Blood may be applied to the soil in a liquid or dried state, either alone or mixed with other manures.

6. COMPOSTS.—The meaning of the term compost has already been explained under the head of weak manures. There it was said that composts are strong, if they contain a large proportion of nitrogenous matter or phosphates. Hence nothing special need be said here.

SECTION V.

Permanent nurseries.

The main points to consider as respects the establishment and maintenance of a permanent nursery are :—

(1) Choice of site.
(2) Area of the nursery.
(3) The form of its boundary.
(4) Fencing.
(5) General preparation of the soil.
(6) Watering.
(7) Laying out of the beds, paths, &c.
(8) Preparation and management of the seed-beds.
(9) Preparation and management of the nursery lines.

ARTICLE 1.

CHOICE OF SITE.

In choosing a site for a permanent nursery we have to consider its two elements :—(i) soil, and (ii) locality.

SOIL.—With respect to the first, it is an exploded idea that transplants should necessarily be raised in soil similar to that of the forest into which they are to be put out. What we require is nothing more or less than vigorous plants well furnished with fibrous rootlets and with a crown strong in proportion, and that soil is the best for our purpose which produces such plants, whether it be like the soil of the forest or not.

Such plants, as we have just referred to, are neither the thin, dry, starved seedlings that would come out of a poor soil, which seedlings, possessing little vitality, would soon succumb under the exaggeration of unfavourable conditions consequent on their being put out in similar bad soil; nor are they highly forced plants, which being overdeveloped, would contain too large a proportion of insufficiently lignified parts to possess tenacity enough to survive a sudden change of conditions for the worse, and would even suffer very appreciably in the mere putting out operations.

But even admitting, for the sake of argument, that seedlings should be raised in soil similar to that of the forest where they are to be put out, what is to be done if the soil there, as is nearly always the case in the enormous aggregate area a single permanent nursery has to serve, varies from place to place through a long series of gradations and even well-marked differences? How is the nurseryman to make his nursery, as respects the soil, so complete an epitome of the immense area, for which he has to raise planting material? And how is it possible to trust the ordinary workman, who plants for us, to put down at any given point seedlings coming from exactly similar soil? Here we evidently arrive at a *reductio ad absurdum.*

But there is still another very important consideration to regulate the choice of soil. A permanent nursery is necessarily intended for raising appropriate planting material belonging to a variety of species, possessing, in the aggregate, very various requirements, and consequently the soil should be such as to suit each and all of those species as closely as possible.

We are thus perforce led to choose a soil of medium quality, *i. e.*, one that is neither too rich nor too poor, neither too wet nor too dry, neither too stiff nor too free. Thus it need be nothing more than a moist sandy loam. If it should happen that a sandy loam is not available, then it is better to select a sandy soil than one which contains a strong proportion of clay. Under the influence of drought a clayey soil would cake at the surface, and in shrinking and becoming creviced, would rend asunder and kill the roots of the seedlings; while during frost it would swell up to such an extent as to leave them ejected as soon as thaw occurred. The sterility and want of sufficient cohesion of a sandy soil can be easily cured by admixture of the necessary manures, whereas it would be a difficult and expensive task to correct the defects of stiff clays. Moreover, a sandy soil is much more easily kept clear of weeds.

As regards depth it does not follow that, because the transplants ought to possess short roots, not exceeding say 18 inches in length, the depth of the soil should also be limited to that figure. With only 18 inches of depth, the soil would nearly always be liable to be overheated under a hot sun, or to become waterlogged during the rains if the subsoil were not freely permeable; and it is always safe to insist on a minimum depth of 3 feet.

Stones in the soil also tend to overheat it, besides injuring the nursery implements and interfering with the easy lifting up of the plants.

The nature of the subsoil is of little importance as long as it is neither impermeable nor too freely permeable. A basis of lime is an advantage, as it prevents the formation of acid humus in the soil, which it at the same time enriches.

LOCALITY.—With regard to the second point, locality, it may be generally laid down that it should not be one exposed to early frosts or to drought, nor should it be so damp as to favour the development of mildew and other fungoid growth. Moreover, it must not be confined in the midst of a lofty mass of forest. It should be just sufficiently inclined to allow water to drain off easily, without, on the other hand, letting it out too fast. In hilly country however, steep ground obviously cannot always be avoided; but even with a rapid gradient, soil, that holds water sufficiently well, can invariably be found. Lastly, it is a great convenience to have a surface spring or streamlet near at hand from which to irrigate the nursery, especially if it runs above the latter and can be diverted into it. The vicinity, sufficiently remote, however, to obviate destructive frosts, of a tank above the level of the nursery is still more to be desired. In the absence of these advantages, a well or wells must be sunk, in which case the water-holding stratum ought to be as near the surface as possible. Occasionally flat expanses of good soil, high enough to be beyond the reach of severe frosts, can be found along the banks of small rivers that run all the year round or contain perennial pools, and in such places the expense of well-sinking can be saved.

As no trees are allowed to stand in the nursery, nor any so near its boundary as to interfere, by means of their roots, with the cultivation of the ground inside, the selection of a blank, which is also otherwise adapted for the purpose, is to be recommended in the interests of economy. But a belt of trees along the boundary, producing useful seed or fruit and sheltering the nursery against cold or scorching winds, is always desirable.

The accessibility of a nursery is a matter of the first importance. In the plains always, and in the hills whenever possible, carts ought to be able to come up to the nursery. And for the forest or forests which it has to serve, the nursery should occupy the most central position available.

ARTICLE 2.

AREA OF THE NURSERY.

The area of a permanent nursery ought, generally speaking, to be at least large enough to occupy fully the time of any special establishment entertained for it. It will of course vary with the area of the forest or forests which it has to serve, with the extent to which artificial methods of stocking or regeneration are resorted to, and with the average age and size of the transplants to be raised. It must be borne in mind that the labour and cost of establishing and maintaining a single large nursery is much less than that required for a number of small nurseries aggregating the same area, except that in the former case the transplants have to be carried out over a longer distance. Nevertheless, unless the distance of lead is very great, the extra cost of carriage per individual plant is generally insignificant, and in nearly every case it is expedient to have a large nursery. It may, therefore, be laid down as a general rule that the area of a permanent nursery should not be less than 4 acres, and in the majority of instances it should be at least 6 acres.

ARTICLE 3.

PERIMETER OF THE NURSERY.

On the outer form of the nursery depends the length of its boundary, and hence the cost of fencing it. It should, whenever possible, be a regular figure. The circle would, theoretically speaking, be the best form to adopt, since for the same length of periphery, it encloses the largest area of any other; and after the circle would come the equal-sided polygon. But neither of these figures are of any practical value, since the arrangement of the irrigation channels, and hence of the beds and paths, must always be rectangular, and would consequently lead to a great waste of space at the periphery. Hence the best figure would be the square, and after that the rectangle. In many cases, however, as in the hills, the choice of site is limited, and there is no alternative but to adopt irregular figures suiting the contour of the ground. Exceptionally, indeed, there are even occasions in which

irregular figures are advantageous, as when a portion of the boundary coincides with the bank of a river which forms a natural sunk fence.

ARTICLE 4.

FENCING.

No nursery can fully serve its purpose unless it is completely protected against the inroads of cattle, elephants, pigs, porcupines, hares, deer, bears, and other destructive animals.

Where flat stones are procurable in the vicinity, and in sufficient abundance, as in most districts of sandstone and gneissose formation, a wall of dry masonry, effective in every way, can be put up at a trifling cost. A pucca wall would of course be the best, but the expenditure required for its construction would, in most cases, be prohibitive. The next best kind of fence would be one of wire stretched on standards of iron or wood or better still on single slabs of stone. Such a wire fence has, however, this disadvantage that it does not stop the ingress of small animals, such as hares, porcupines and even young pigs. But if funds are available, that defect is easily remedied by means of wire netting, or, in the contrary case, by putting up against the wire fence a dead thorn one formed of branches of *Zizyphus*, khair, or any other spiny bushes abundant in the vicinity, similar to those erected every year round fields in most parts of India. The branches should be inserted a few inches in the ground by their lower extremity and secured to the wires with slips of fibrous bark or with withes, the whole work being executed without any extra expenditure by the nursery establishment during their many leisure half-hours. The wire fence just described would with most advantage be erected on a mound formed by excavating an open ditch, about 18 inches deep and 2 feet wide, along the boundary and throwing up the earth along its inside edge (Fig. 22). The sections of both mound and ditch should be an equal-sided trapezium and would necessarily be equal in area. *A berm* or *scarcement*, AB, should be left between the mound and ditch to prevent the earth slipping into the latter. The mound should be thoroughly well rammed before the fence is put up. The advantage of the combined mound and ditch is that they reduce the height of the wire fence required, while the ditch, besides serving as an additional protection, also performs the office of a drain. When the nursery is situated on a pronounced slope, the ditch and

mound cannot obviously be employed, since they would only facilitate the erosion of the soil. On such slopes no special protection will be required along the lower edge of the nursery, since the retaining wall of the lowest terrace (see Article 5, page 167) would be as good as a sunk fence.

All tight-bound fences of wooden posts and wattling are entirely out of place in this country, where white ants and destructive weather influences would necessitate their constant renewal. Moreover they would be no barrier to pigs, porcupines and hares.

Live hedges, of species varying with the forest region, may be employed when the area of a nursery is very large, which would be the case if the nursery were used also as an experimental forest garden. But, in any case, more effective internal fences would be required for the portion of the area devoted to real nursery work. Live fences have for the most part this prohibitive disadvantage that they harbour noxious vermin, besides, when not thorny, giving free access to hares, &c. The principal species best adapted for live fences are—in the Himalayas, *Cratægus, Pyrus Pashia,* roses, &c.; in the plains, species of *Euphorbia, Zizyphus, Carissa, Cæsalpinia, Capparis horrida, &c.*

The best way to keep out elephants is to surround the nursery with a ditch about 5 feet wide and at least 3½ feet deep, and with sides making an angle of not less than 60° with the horizontal. As an extra precaution the bottom of the ditch may be studded with sharp stakes.

ARTICLE 5.

General Preparation of the Soil.

First Cultivation.

The first thing of all to do is to clear the ground of every tree and shrub; and here we may, therefore, describe in a brief manner, without trespassing on the province of Forest Utilisation, the best implements to use for the purpose. They are felling-axes, bill-hooks, picks, grubbing-axes and the hoe-axe.

Felling-axes and bill-hooks are too well-known, for all practical purposes, to need any special notice here. A complete account of them will be found in any work on Forest Utilisation.

Picks.—There are several varieties of these, some having pointed, others cutting ends. As they are used for penetrating and loosening hard soils or gravels, or for cutting roots among gritty

and stony particles, they require their ends to be well steeled and tempered. All varieties of picks agree in being curved, the radious of curvature being more or less equal to the combined length of the handle and the labourer's arm. The best form of this tool is the *pick-axe* (Fig. 13), one end of which is pointed and the other flattened into a cutting edge at right angles to the direction of the handle. The length of the head may be from 24 to 30 inches, that of the handle about 3 feet, and the breadth of the cutting-edge from 3 to 4 inches, or even more if circumstances render it desirable.

THE GRUBBING-AXE—Figs. 14 and 15 represent two common and very useful forms of this implement. It is used for uncovering and undermining, as well as for cutting, roots. The handle is of the same length as that of the pick. The term mattock is used indifferently to designate this as well as the tool next described.

The HOE-AXE. This is somewhat similar in structure and application to the transversely flattened edge of the preceding implement, but is more strongly made and broader, and has a longer handle. Its use is chiefly to cut up bushes by the crown of the roots. Figs. 16 and 17 represent two common forms.

Instead of first felling a tree and then extracting the stump, the easiest as well as the most economical and effective plan is after uncovering the main roots, to cut through these. The force of the wind alone, aided if necessary by pushing or pulling, causes the tree to lean over to one side far enough for the immense leverage of the crown and trunk, as the tree falls, to rend asunder all the smaller and lower roots, and the extraction is thus immediate and complete. This mode of operating also shakes the soil very effectively, thereby facilitating the future tillage.

The next operation is to level the ground. In the plains, if the surface of the soil is more or less even and has only a slight slope, and provided the length of the nursery in the direction of the slope is not great enough for there to be any very appreciable difference of level between its lowest and highest portions, this end is accomplished simply by means of the ploughing operations, followed by a few sufficiently heavy falls of rain. The deeper depressions, will however, have to be filled up in a special manner, and this would generally be best done by bringing in good topsoil from outside the nursery.

If, all other circumstances being the same, the difference of level is marked, exceeds say 4 or 5 inches in 100 feet, the area must be divided off into horizontal terraces, the edges of the terraces being protected against slipping or erosion by means of retaining walls of dry masonry. Pucca walls, being necessarily built on solid foundations, would be excessively costly, and also have the drawback of impeding a sufficiently free drainage.

The labour of terracing will obviously be directly proportional to the steepness of the slope, and the width of the terraces will equally obviously vary jointly with the angle of slope and the depth and richness of the topsoil, for the subsoil should, as far as can be helped, nowhere be exposed or even brought too near the surface. Moreover, in forming the terraces, the height of each terrace ought to be so chosen that the cutting shall, as far as practicable, be equal to the quantity of embankment, in order thereby to minimise both the labour of cutting and the distance of lead for the earth cut, and to utilise every bit of this latter.

The use of a levelling instrument is always indispensable, as the best work with the eye cannot but fail at many points, and cause hereafter much annoyance, serious loss of good planting material, and heavy expenditure on frequent repairs of broken terraces and eroded soil.

Under any circumstances, we cannot, in most parts of India, get rid of the necessity of protecting the soil against erosion, since every year heavy falls of rain occur, a large proportion of which, not being able to enter the soil as fast as it falls, rushes over the surface, cutting channels in it, and carrying away a considerable portion of the top-soil, especially if this has been loosened by cultivation.

Whatever the character of the ground, the following grand rule should be universally observed:—The rain falling on higher land outside the nursery should in no case be allowed to run down into the nursery, except it be along a natural, well-defined drainage channel passing through it, which it has not been found possible to close; nor ought any portion of the fall within the limits of the nursery to be permitted to be carried off outside by *surface* drainage.

In the plains, the mound system of fencing, already described on page 164, answers perfectly as a protective work. The mound prevents a rush of water both into and out of the nursery; while the ditch serves not only to drain off with sufficient rapidity any

excess of moisture in the soil of the nursery itself, but carries off all the surface drainage of the higher ground outside. Indeed, when the fall of the ground does not exceed about 1 in 200, the mound alone is so effective that it is common to see large fields as it were walled off by mounds of mere earth into a number of very nearly level compartments. Any slight difference of level that exists is soon corrected by rain, and the compartments then form a succession of low terraces with earthen parapets.

In the hills, besides having to support the terraces by a retaining wall, as already described, a violent rush of water over the edges, and the consequent washing off of the soil, must be prevented by sloping the terraces slightly inwards: the rain caught by each terrace will soon drain away quietly through the soil and out by the retaining wall, and if there should be any slight excess, this will pass out by way of the irrigation channels without doing any damage to the nursery. The rain falling on the slopes above, if they comprise an area large enough to receive an appreciable fall during a single shower, can be easily diverted, by means of one or more channels, into the nearest ravine or gully.

If due care has been exercised in the choice of the nursery site, special drainage works will hardly ever be necessary. In the rare event of their being required, the directions given in the next Chapter for the construction of drains would generally apply.

The next point to attend to, after clearing and levelling the ground and protecting the soil against erosion, is the freeing it of all its larger coarse elements down to at least 18 inches below the surface. The object of this operation is to have the soil contain nothing that would blunt the sharp implements of the nurseryman, and also to give it a uniform texture and to prevent heating.

Stones lying on the surface ought to be at once picked off those below the surface being got rid off during the progress of the actual tillage. Where the stony element is at all abundant, some of it will still remain even after the tillage operations have been completed, and will have to be removed by sifting or screening when the nursery beds and lines are prepared, as explained further on.

Lastly, we have to consider the tillage or real preparation of the soil, the object of which is to remove and kill the roots of all existing growth and to loosen and comminute and, if necessary, also to correct the defects of, the layer of the soil that is to

contain and nourish the roots of the plants to be raised. But in thus breaking up the soil, care must be taken to bring up to the surface as little as possible of the under-layers, which have never been exposed to fertilising weather influences. By keeping at or near the surface all the richer portions of the soil, the lower layers get the full benefit of the soluble substances of plant-food carried down by rain or irrigation water; whereas if these richer portions were allowed to go to the bottom, the sinking water would carry away with it no inconsiderable amount of those substances completely out of the reach of the roots of the young plants, while the upper roots would derive no benefit at all from them.

If the operations preceding the tillage have not already removed the low vegetation that covers the ground, this should now be got rid off. Amongst native gardeners and agriculturists it is usual to burn off this vegetation. Such a plan is, however, to be deprecated (except on acid or stiff clayey soils, which should, in the first instance, never have been chosen), as its only recommendation is a very petty economy, while it not only destroys the organic matter in the top layer of the soil, but also bakes this latter. There is no alternative but to use the grubbing axe, scythe or sickle, and to carry away out of the nursery area or to the manure pit all the rubbish cut. Nevertheless, if the quantity of this is not considerable, it may be collected into small heaps up to a foot high equally distributed all over the area, and fired on a calm, dry day so as to ensure complete combustion. Half-burnt remains of the rubbish would be strongly acid, and, if introduced into the soil, would still further injure growing plants by their subsequent decomposition during the first ensuing rains and the heat thereby developed. The succeeding tillage operations will suffice to mix the ashes thoroughly with the soil.

The deeper the soil is turned up, the better; and hence, theoreticall speaking, the pick or hoe would always be the best implement to use. But the progress of work with those implements is necessarily very slow, and, except on narrow terraces, on steep hillsides, where no other implement could be employed, they must always yield the place to the plough. Whatever the pattern of plough adopted—and this will vary greatly in different parts of India—the share must enter the soil deep enough to tear up completely once for all the vivacious roots and underground stems of existing vegetation. If any fragments of these are allowed to

remain in the ground, they will soon multiply and render the nursery work impossible. The creeping roots of woody species that throw up suckers cannot, however, always be entirely got rid of with the plough, as they often (*e.g. Phyllanthus Emblica Boswellia thurifera, Ougeinia dalbergioides Diospyros Melanoxylon,* &c.) go down to a depth of 2½ feet and more, and hence the only way to deal with them is to dig them out one by one, with a pick or hoe, whenever and wherever a sucker or stump shows itself.

Deep cultivation is justifiable for the following four reasons:—(i) It is the only way to kill out all existing growth and to clear the soil of roots and underground stems; (ii) The entire layer of soil, in which the roots of the seedlings to be raised are to spread and be nourished, can never be sufficiently loosened and comminuted; (iii) The loosening and comminution are absolutely necessary in order to admit air, with its carbonic acid and nitrogen compounds, into the lower layers of the soil and thereby fertilise them; (iv) While it prevents a sudden excess of damp in the layer of the soil occupied by the nursery plants and preserves them from what has technically been called *wet feet,* it also helps to preserve moisture in it during drought and encourages the formation of dew in its innermost layers during the Cold Season.

The best time of the year to begin ploughing is the Cold Season: the soil is then soft and yielding while the sun is quite strong enough, or the cold great enough, to destroy the vitality of the roots and underground stems torn up. One or two women or boys should follow the plough and pick or pluck out all stones and roots brought up to the surface. If the land has had woody growth on it, the ploughman should be armed with a light axe with which to cut through all roots sufficiently strong to arrest the progress of his plough. A coulter (Fig. 18, C) fixed to the shaft of the plough, and strong enough to cut through woody roots up to 1¼ inches thick, will facilitate and expedite the ploughing work very considerably.

The ploughing should be repeated at least twice, each time in a direction at right angles to the preceding one.

Numerous fragments of roots and underground stems will, however, still be left in the soil, and the next operation will be to work it successively in two directions, at right angles to one another, with the bullock-hoe (Fig. 19), the size of which will be proportionate to the depth to which the plough has penetrated. This

hoeing will shave away all the ridges necessarily left by the plough; cut and break up the larger clods; catch, cut or tear and bring up to the surface nearly all the remaining roots, which, together with stones, must be picked off, as before, as soon as they show themselves; level the ground by cutting away eminences and dragging fresh earth into the depressions; and thoroughly mix up with the top soil any manure scattered over the surface. The clods are still further reduced by means of a log-roller or special clod-crusher drawn by oxen. After this it is advisable to hoe the soil over again in the same manner as on the first occasion.

The soil should then be left to lie thus until the first fall of rain has thoroughly soaked it, when it should be hoed over once more in the same manner as before. The result of this last hoeing will be that all the last clods, large and small, will be thoroughly comminuted, the soil acquire a soft, uniform texture, and the surface be evenly levelled.

The procedure just described will answer in the very stiffest soils, for which indeed it is especially well adapted. Under exposure to the air, the clods, drying up irregularly, crack and, to a very great extent, crumble to pieces of themselves or become easily pulverisable. The comminution is still further assisted by the innumerable particles of organic matter scattered throughout the soil and which, absorbing oxygen and thereby increasing in bulk, become each a centre of activity for loosening and breaking up the clods.

If the soil is acid, the repeated turning up to which it subjected and the fine state of comminution to which it is reduced by the method here recommended, secures the early and complete oxidation of the previously imperfectly decomposed organic substances that caused the acidity.

When the soil is naturally of a free texture, and roots, especially those of grasses, are not numerous and troublesome, for the bullock-hoe we may substitute a strong wooden harrow (Figs. 20 and 21.)

The entire area of the nursery ought to be cultivated in the manner described, *i.e.*, not only the portions that are to comprise the future seed-beds and lines, but also those which will constitute the roads and paths; for, as said before, the smallest remnants of vivacious roots and underground stems left anywhere in the nursery will soon multiply and spread, and not only cause much

trouble and expense in the future, but also impair efficiency very materially, and unfit a considerable portion of the area for the purpose for which it is required.

If the soil is poor in bases, as when it is a stiff clay or a nearly pure silicious sand, it is advisable to strew quicklime or, which is generally more economical, finely ground *kankar* over the surface just before the last two hoeings. The quantity of lime or limestone to use will depend on the nature of the soil in each particular case. Beyond the liming no manures should be applied until after the nursery beds and lines have been laid out.

It is much to be recommended to grow a previous crop or two of potatoes, Indian corn, rice, *Sorghum*, sugarcane, sesamum or cotton, whichever is the most suitable, before laying out the area as a nursery. The cultivation of such crops, all of which require very thorough weeding, effectually clears the soil of every trace of the previous vegetation that covered it, corrects all its harsh qualities, loosens it thoroughly, renders its texture perfectly soft and even, and completes the levelling of the ground. Potatoes, sugarcane, and cotton are the best crops for our purpose, as cereals and oil-seeds attract rats and mice. While improving the soil and site, these crops will also yield a large money return, covering, in many cases, the entire outlay on the preparation of the soil

Subsequent Cultivations.

If the nursery has been completely utilised and carefully maintained, the wholesale style of preparation described in the preceding paragraphs will never again be required.

But it may frequently happen that a considerable portion of the area has not been used for a season or two and weeds have, in the meantime, sprung up. In that case, if the growth of weeds is not very strong, two ploughings, followed by two hoeings or harrowings, will suffice to restore the soil to its original high condition of tilth. If strong weeds have overrun the soil, they may, before the plough can be used, have to be cut or shaven away with sickles, pickaxes, grubbing axes or hoe-axes, according to the size and lignification of the weeds and the nature of the soil.

Otherwise it will be sufficient to merely hoe the soil where required. An excellent form of tool for this purpose is the tea-planter's hoe (Fig. 22).

ARTICLE 6.

WATERING.

In the climate of India, which admits everywhere of a more or less prolonged Dry Season, watering in some form or other cannot be dispensed with. Even in the few exceptional cases in which the intervals between sufficient falls of rain are not long enough to kill the young nursery plants outright, these, especially such as are in the seed-beds, are necessarily thrown back in their growth, unless watered artificially. And indeed, under any circumstances, it is a matter of vital importance for the nurseryman to be able to regulate his work and control the growth of his young plants without being entirely dependent on the contingency of rain falling.

The necessity of artificial watering being then indisputable, it may generally be laid down as a rule that for nursery purposes the usually soft, tepid water of a flowing stream is better than the generally hard, chill water of a spring. Tank water would obviously be even still better.

The chill of cold water is most easily corrected by storing it in a reservoir previous to use. This storing also affords an opportunity for mixing special soluble manures with the water, an expedient which, as will be seen further on, is often useful and even necessary for preventing or diminishing the ravages of white ants. The reservoir, in order to minimise waste by absorption in the soil, by evaporation, &c. should be situated in the immediate vicinity of the nursery.

Water may be given to the plants either (A) by pouring it from above, *i.e.*, by HAND-WATERING, or (B) by IRRIGATION.

Handwatering.

In hand-watering the supply of water may be brought from a distance in skins, or led in channels, from wells or tanks or running streams into reservoirs, either of pucca masonry or with merely puddled sides and bottoms, and situated in the midst of the beds or lines to be watered. Hand-watering is always both costly and slow. Under the most favourable circumstances its effects are only superficial and therefore not lasting; and hence, when it has once been begun, it must be continued nearly every day until the first fall of rain thoroughly soaks and softens the soil. When it is effected with watering-pots or ordinary garden pumps, a hard crust of fine mud, impermeable to air and dew,

forms on the surface of the soil and has to be broken up by light hoeing as often as the watering takes place. This very objectionable contingency may, to a limited extent, be obviated by the use of the garden syringe, which consists of a forcing pump whose spout is furnished with a fine rose; the water is ejected through the rose with great force in a shower like rain, which, besides moistening the soil, washes off the dust, &c. clogging the green parts of the young plants. Whether pots or pumps or syringes are used, the water must penetrate as far as the roots to produce any useful effect.

Hand-watering in permanent nurseries has its *raison d'être* only in the hills where drought is neither prolonged nor severe, and even then only in the absence (exceptional it must be said) of running streams or surface springs immediately above the nursery site. It may also be employed immediately after seed has been sown, and it is the only method practicable with plants in baskets or garden pots.

Irrigation.

In all other cases irrigation should be resorted to: it is much cheaper, much more effective and much more expeditious, and requires very much less trouble and labour than hand-watering.

The ordinary system followed by European nurserymen is to lead the water, from whatever source obtained, into horizontal channels running between the beds and lines parallel to their longest dimension. The water is never allowed to flow over the beds, and is retained in those channels until the soil of the beds or lines, as the case may be, is thoroughly drenched. The precaution of keeping the water off the beds and lines is taken to prevent the formation of a superficial crust of mud. For convenience sake we will term this the LATERAL PERCOLATION, or simply the PERCOLATION, system.

A common method employed by native gardeners and agriculturists is to enclose the beds and lines with a continuous ridge of earth 5 or 6 inches high and then, by admitting water inside, to flood them to a depth of 3 or 4 inches. By this means the soil is perhaps more effectively drenched than by the percolation system, for the water let in over the beds sometimes stands as much as an hour or more before it is completely absorbed—no slight advantage, it must be admitted, under the strong Indian sun. The work is also perhaps done a little more expeditiously. But, on the other hand, the formation of a superficial crust o.

mud, which must afterwards be raked and broken up, is inevitable. The method just described may be termed the FLOODING system.

Whether the percolation or flooding system be employed, the effect is the same as regards the total destruction or banishment of white ants, rats, mice, and other burrowing animals, the depredations of which seem only to be aggravated by hand-watering.

Another of the numerous advantages which irrigation possesses over hand-watering is that it succeeds in shallow soils where the latter, from compelling the roots to remain entirely superficial, completely fails.

Although implied under the head of site, it may be stated here that the spring or tank, from which the water-supply may be obtained, should not be so near the nursery as to keep the soil constantly in a thoroughly saturated state, which would not only prevent healthy root-aëration, but also aggravate the effects of frosts.

When the tank, spring, or stream is on a lower level than the nursery, the water has obviously to be lifted. Of the various water-lifts in use in India the best to adopt, according to circumstances, are the Persian Wheel (of which there are several forms), the Double *Mot*, *Charas*, *Chars* or *Charsa*, the *Dheki*, *Dhenkul* *Dhenkli*, *Dhenguli* or *Dhinguli*, and the *Láthi Kundi*, all which contrivances are too well known to need being described here. The water thus lifted can be led away at once into the nursery beds and lines, or stored up in a reservoir until wanted. When the distance of lead is considerable, say exceeds 50 yards, iron pipes, or cheaper still, gutters of wood or sheet iron, supported on wooden or iron trestles, are easily and economically set up. Masonry channels, if on a large scale, are extremly costly, and earthen embankments, however well puddled, are very wasteful, and require constant looking after.

In the absence of all other sources of water-supply, the only plan is to sink wells, the number and size of which will depend on the area of the nursery and the abundance of water in the stratum in which they are sunk. The most effective water-lifts to employ in this case would be the Persian Wheel and Double Mot.

The best time of the day for watering is, according to the experience of Indian gardeners and agriculturists, the afternoon.

The explanation of this, as far as the hot weather is concerned, is obvious, for watering early in the day would result in a very large proportion of the water being lost by simple evaporation. But as regards the cold weather, in places exposed to night frosts, it is evident that the later in the day a plant is watered, the larger will be the quantity of moisture contained in its tissues, and hence the slighter its resistance to frost during the night. Hence the proper plan in the cold weather would be to perform the watering in the forenoon; and if from wells, as early in the day as possible, since during that period of the year well water is always much warmer than both the air and the soil in the morning. But indeed, whenever practicable, watering ought to be entirely dispensed with in frosty situations during the Cold Weather.

When there is advantage in watering in the afternoon, the whole or portion of the water-supply that is available in the forenoon can, if necessary, be stored up in reservoirs. Such storing is unavoidable when the discharge of the canal or natural stream, on which the nursery is dependent, or the copiousness of the spring feeding the wells, is insufficient to irrigate the required area within the specified time.

ARTICLE 7.

Laying out of the Nursery.

In laying out the interior of a nursery two main points have to be kept in view: (a) how to make the best use of the given area, and (b) how to perform the watering in the most economical and effective manner.

For every permanent nursery there should be a good set of offices for the establishment and for storing tools, seeds, &c. If the area is large, these buildings should be situated at or near its most central point in order to facilitate constant supervision both by day and night. If the area is limited, they should be erected immediately outside, and this can obviously, for the very reason that the nursery is small, be done without in any way impairing efficiency. The cattle used in connection with a nursery ought invariably to be stalled outside.

In large nurseries it is generally advantageous to have a cart-road leading up to at least the nursery buildings, and, if possible, also carried further on, so as put it within easy reach of every part of the area. To economise space as well as money, it is expedient to give it only sufficient breadth for a single cart, but

widening it at its extremity or at certain intervals so as to enable the cart to turn or cross or pass another. The road should be metalled and have a slightly convex section. It ought also to be raised somewhat above the level of the adjoining soil on each side, and be protected with well-made side-drains. One corner, generally the shadiest and most protected of the nursery, ought to be specially set aside for preparing and storing manures.

The next step is to lay out the paths and nursery beds. These latter should be just broad enough for a boy 9 or 10 years old to easily reach the middle without having to step or rest on them. A breadth of 40 inches is very convenient. Their length would be limited only by the shape of the ground and the number of plants of the several species to be raised; and they ought always to be rectangular. The beds must be divided off from each other by paths about a foot wide. These would be more or less parallel to each other and comprise two sets crossing one another at right angles, one set abutting perpendicularly on the cart road, when there is one.

When the nursery is to be irrigated, the paths running parallel to the longest dimension of the beds should follow horizontal lines, and the water, instead of reaching the beds directly from the source whence it is obtained, should previously come down a primary or FEED channel, of sufficient width and depth, from which it would be diverted at right angles, to the right and left, into smaller secondary or DISTRIBUTING channels about 6 inches wide and 4 inches deep, and running between each bed and the path immediately above. In Europe the paths running parallel to the beds serve themselves as distributing channels; but in India, where a large quantity of rain often falls within a limited time, the paths, if used as watercourses, would be rendered quite unfit for circulation, and, if used for circulation, would be rendered unsuitable for irrigation. Hence in this country it will not unfrequently be expedient to beat the paths firm and to cover them with gravel, clinkers, coal cinders, &c. It is evident that midway between every two successive paths of the series running at right angles to the lie of the beds there will be a feed channel, and that every distributing channel will terminate at the path on which it abuts.

In the percolation system of irrigation the surface of the beds ought evidently to be slightly raised above the paths, say about 2 inches. This is easily done by cutting a portion of the top-soil off the paths and throwing it on the beds. The adjoining distributing channels act as side-drains during a shower of rain, and protect the paths from being washed away. The irrigation water, as it comes down, is retained, by means of small removeable dams, in the distributing channels, until the adjoining bed or beds are thoroughly drenched. These dams are simply a square or rectangular piece of wood, earthenware, sheet iron, or stone placed across the feed channel in a continuous line with the lower edge of two adjacent distributing ones, and standing just a fraction of an inch below the level of the path on each side, so as to prevent the water from ever rising high enough to flow over those paths. On even open ground the disposition of the beds, paths, and channels would be as represented in Fig. 23, where B B are the beds, P P the paths, D D the distributing channels, F the feed channel, and d d the dams.

When the dimension of the nursery in the direction of the length of the beds is too great for a single system of feed channel with its distributors to perform the irrigation conveniently and efficiently, there must be more than one such system laid out; and, when this is the case, the feed channels should themselves be fed from a main one running at right angles to them at the highest end of the nursery.

On hill sides the feed channels on each terrace must obviously receive their water directly from those immediately above them; and hence, to prevent erosion, it is necessary to pave them, if not along their whole length, at least at both their extremities. In hilly country flat stones adapted for this purpose are, as a rule, easily obtainable, and both the sides and bottoms of the channels can be protected in this manner at a trifling cost. But a simpler expedient is to form the channel of two planks joined edgewise, as shown in Fig. 24.

At the upper end of the feed channel on each terrace, a wooden cask may be let into the ground to receive the water falling from above, and of sufficient capacity for any sudden emergency that may arise. Instead of placing a cask, a small stone-lined tank or well may be built.

If the flooding system of irrigation is employed, it is evident that the beds must be lower than the paths, and indeed, on the

same level as the distributing channels. The water is usually turned into any one of the distributing channels by damming up with mud the feed channel just below the former, and it is then admitted into the beds by removing, with the hand or a hoe, a few inches length of the ridge flanking the distributing channel and restoring it as soon as the beds are sufficiently flooded, the dam placed across the feed channel having been previously removed. It would be a great improvement, and one easily effected, to maintain a permanent opening in the ridge of earth, and to fit into it a moveable dam formed of a piece of wood, flat stone, hard earthenware or sheet iron. Similar dams should be used also in the feed channel. In every other respect the arrangement of beds, paths and channels would be the same as in the percolation system.

ARTICLE 8.

Preparation and management of seed-beds.

Before proceeding to describe the actual preparation and management of the seed-beds, it is necessary to say a few words regarding the process of germination and the methods of forcing it, and the time for sowing the seeds.

§ 1.—*Germination and methods of forcing it.*

In the germination of all seeds three distinct stages may be recognised :—

(i) The Imbibition of Water.—First of all the germ and also the perisperm, if there is any, absorb water and swell up. The higher, within certain limits, the temperature is, the more rapidly does this process take place. The covering of the seed may also absorb water and become more soft and yielding.

(ii) Chemical Changes of State of the Reserve Materials.—Under the influence of heat, within certain limits, and the special ferments present in the seed, the water-gorged reserve materials absorb oxygen from the air, and from generally insoluble substances incapable of directly forming plant tissues, become converted into soluble substances capable of at once becoming living tissue.

(iii) Development of the Embryo.—By means of the newly formed substances, under the continued influence of moisture, heat and oxygen, new cells are formed in the embryo, which thus increases rapidly in size, breaks through the enclosing shell and develops into a perfect plant. This stage begins before the completion of the second, and much of it is contemporaneous with it.

It is evident that the first stage can be entirely, the second stage partially, completed before the seeds are sown, thus diminishing the time during which they will have to lie in the soil before the embryo becomes a perfect plant. To allow the second stage to be entirely completed would result in most cases in risking the safety of the seeds from the inevitable handling they must be subjected to in the act of sowing. There are various methods of securing this partial completion of the germinative process, or, as it is termed, of forcing germination.

First of all, the seeds may be soaked in ordinary water, either by submerging them or by putting them into baskets wherein they are kept constantly moist. The latter method is the better of the two, as it allows air to pass in freely between the seeds, and with the air a certain amount of heat; but some seeds, like teak, which have a hard horny shell that absorbs moisture with difficulty, are best kept submerged, heat being given by artificial means or by placing in the sun, air by frequent stirring. The length of the soaking will, of course, depend on the nature of the seed. Some seeds, especially such as are very hard and dry, may be first soaked for a few seconds or minutes in water raised to a temperature of about 200° Fah. Some times the seeds are put up in heaps and moistened and allowed to undergo a certain degree of fermentation, which of course helps germination. The absorption of water by the embryo and the necessary chemical changes may be promoted by subjecting the seeds to the action of certain reagents in solution in the water, such as chlorine, bromine, iodine, monobromide of camphor, lime, and weak acids, which render the shells porous. Limewater, moreover, revives in some cases the germinative power of the embryo. Lastly, the seeds may be soaked in liquid manure; this contains in addition to chlorine and certain organic acids, also slimy matters which help to keep the seeds moist and enable them the better to absorb moisture from the soil.

In the case of seeds, which, like teak, have a hard impervious shell, and which on that account germinate with difficulty, thorough soaking followed by drying, this alternation being repeated once or oftener if necessary, is not unfrequentl the most effective method of inducing quick germination.

§ 2. *Season for sowing the seeds.*

The season for sowing the seeds will depend on the species in question and on the age and time at which the seedlings are to be removed from the seed-bed.

Absolutely speaking, for all places where no snow falls or, although it falls, does not lie for any length of time, the commencement of the summer rains is the best time for sowing, as every condition in nature is then favourable for early germination and rapid growth, and the seedlings have the entire rainy season in which to gain the strength necessary to resist the October sun, and where, there is a true cold weather, the frosts of winter. But in the case of some species the nature of the seed itself fixes the time when it should be sown. For instance, the acorn of *Quercus semecarpifolia, must* be sown in the middle of the rains, when it ripens. Similarly for sal there is no other period for sowing but the commencement of the rains. Where snow falls and lies throughout the greater part of the winter, the best time for sowing is the autumn, as the seeds cannot be better preserved from all harm than under the protecting covering of snow. Becoming thoroughly saturated with moisture under the snow, the seeds germinate during the first warm days of spring and the young plants are already pretty strong by the commencement of the summer rains, throughout which they continue growing on right up to mid-autumn.

For seeds that have a protracted germination, like teak in most parts of India proper, ber, &c. the end and even the middle of the hot weather is the best time for sowing, as germination is thereby forced and takes place at the very first burst of the monsoon, and the seedlings, whether at once transplanted or kept in the seed-bed, have the entire rainy season during which to strengthen themselves for the unfavourable time of the year that immediately ensures. And generally speaking, whenever seedlings from a few days to two or three months old are required, the seeds should be sown a sufficient number of days before the approach of the summer rains.

§ 3. *Actual preparation of the beds.*

The style of seed-bed depends entirely on the method of planting out employed and, in pit planting, especially on the form and size of the pits; but broadly speaking we can have only three kinds of seed-beds :—The seedlings may be raised either (a) in ordinary seed-beds, or (b) in cylindrical tubes sunk into the ground flush with the surface, or (c) in ordinary flower-pots or baskets.

A. Ordinary seed-beds.

First of all, the layer of soil in which the seedlings are to spread

their roots should be thoroughly sifted or screened, so as to free it from all gravel and coarse grit.

As in each case only a certain maximum length of roots is required, it is clearly an advantage to prevent the roots from going down beyond the fixed depth. The roots can of course be shortened by actual amputation (to be described lower down), but where excessive moisture is not to be feared, it is frequently advisable to form, at the required depth, a hard floor, through which the roots of the seedlings will be unable to penetrate. This floor may be made of kankar or gravel or broken bricks and tiles well-rammed down; but the very best material, both on account of their porous and absorbent nature and manurial qualities, would be pounded charcoal or coke or coal cinders. A masonry floor or one of flagging would obviously be objectionable, as it would be impermeable to water and the seedlings would suffer from wet feet. Moreover, by reason of the organic acids they contain, the roots would ultimately eat their way through the masonry and thus necessitate frequent renewal or repairs. After the floor is formed, the sifted soil should be put back. The surface of the beds should always be carefully levelled with a rake or any other convenient implement.

Simultaneously with the levelling the necessary manure should be raked in. In very free soil the manure ought to be kept near the surface, while in stiff soils it should be mixed with the soil almost as far down as the roots of the seedlings are required to penetrate. The stiffer the soil is, the more energetically does it retain soluble and insoluble matters mixed with it and prevent these from reaching roots outside it; whereas in free soils, rain as well as irrigation water can carry manure from near the surface down to the lowest roots, and manure raked in deep would either be lost or encourage the roots of the seedlings to go down too deep.

For the very reason that stiff soils retain extraneous matters with great energy, and yield them up with difficulty to plants, they should also be manured more heavily.

B. Cylindrical tubes let into the ground.

These tubes are either formed of two semicylindrical tiles of sheet iron, tin or porous earthenware bound together, or consist merely of hollow bamboo internodes. The only advantage their employment offers is the easy removal of the seedlings. But as there are very few species that cannot be transplanted from an

ordinary seed-bed with at least equal ease and success, the system in question is suited only for those few exceptional species that cannot stand any appreciable injury to their roots, and to the still more exceptional case of seedlings being required with a long tap-root and few side roots or root fibres. The system is extremely costly as regards both the nursery work and transport to the forest, and should therefore be altogether avoided in permanent nurseries, unless the area to be planted up is in the immediate vicinity.

G. Flower-pots and baskets.

Plants raised in flower-pots or baskets are carried to the place, where they are to be used, without being removed from the pots or baskets and are thus saved from all risk of injury to their roots. There is no advantage in raising small plants by this method, since they can always be transplanted with perfect ease and safety from an ordinary seed-bed. The method has its *raison d'être* only in the case of large plants required for avenues, groves, fields, hedgerows, parks and gardens. The pots and baskets should be filled with thoroughly well manured soil, the pots having, in order to secure proper drainage, a hole at the bottom covered with a potsherd. The baskets have obviously to be lifted off the ground from time to time to prevent the roots of the seedlings from getting into the ground.

§ 4. *Manner of sowing.*

Under this head there are four separate points to be considered (i) the disposition of the seeds, (ii) the quantity of seeds to sow, (iii) the depth of sowing, and (iv) the method of covering the seeds.

A. Sowing broadcast.

In sowing broadcast the quantity of seed to be used will depend on the nature of the seed and the age at which the young plants are to be removed. For instance, in Central India, where a bed of teak once sown goes on producing seedlings for three consecutive growing seasons, we cannot sow too thickly, even to the extent of completely covering the ground. Again, there are certain species, like *Anogeissus, Adina, Stephegyne, Nauclea,* &c., a very large proportion of the seeds of which are usually barren; in their case also the beds should be literally covered with a layer of seeds.

Small or light seeds that are easily blown away by the wind and are difficult to scatter evenly, should, before being sown, be

mixed with a sufficient quantity of vegetable mould, surkhi-ash or some compost.

As regards covering, some seeds, as for instance teak, need not be covered at all, unless it be with a little chopped straw in order to counteract excessive evaporation and help germination by its decomposition. With these exceptions, all seeds after being sown must be covered over. The depth of covering will depend chiefly on the size of the seeds. Small seeds produce plants with a comparatively short hypocotyledonary stem and must not, therefore, be sown so deep that the cotyledons cannot emerge from the soil and stand up well above it. The larger the seed, the more carefully must it, as a rule, be protected from drought. Large seeds should therefore be sown deep, but not so deep as to prevent a sufficient amount of air from reaching them. A safe rule with large seeds is to given them a covering of more or less the same thickness as their own cross dimension; but it must not be forgotten that, for each kind of seed the depth of covering must vary with the facility with which it germinates.

In covering seeds the usual plan is to sprinkle some light spongy manure, such as, for instance, vegetable mould or a mixture of vegetable mould and farmyard manure, over the bed and then rake it over, by which means the seeds not only get covered, but the layer of soil containing the seed is in every way rendered as suitable as possible both for germination and the subsequent nutrition of the young plants as soon as they come out. Large seeds, when to be sown deep, must of course be pressed into the soil one by one; but no amount of care can secure their being covered over to a uniform depth, and hence they are not, as a rule, adapted for broad-cast sowing.

Value of the System.—Sowing the seed-beds by scattering economizes both money and labour as far as the actual sowing is concerned. But the seeds seldom germinate uniformly. If the sowing has been done thickly, the plants are inevitably too crowded at a great many points, and must suffer, unless early thinned out or transplanted into nursery lines; if the sowing has been done sparely, the soil is insufficiently covered in many places and thus deteriorates or, at the best, there is considerable waste. In either case the disadvantages are serious. In addition to these drawbacks, weeding and the lifting up of the seedlings becomes a troublesome matter. Moreover, as shown above,

large seeds are not always suited for this style of sowing. Nevertheless when seed is plentiful or cheap or the young plants are not to remain long in the seed-bed, or the nature of the seed sown is such that only a small percentage may be expected to germinate, the broad-cast system is often to be recommended.

B. Sowing in lines.

The lines must obviously be straight and parallel amongst themselves and to either the longest or shortest dimension of the seed-bed. They may be either equidistant or two and two nearer together alternately.

The distance between two consecutive lines or pairs of lines will vary with the size of the seeds (large seeds will naturally produce large seedlings), the rapidity of growth of the seedlings, and the age at which they are removed.

The seeds may be sown either on *ridges* or in *furrows*.

Ridges.—Ridges may be made by drawing together the soil in lines with a common hoe, or with a special draw hoe, the crane-necked hoe (Fig. 25), in which the handle fits into a socket formed at the end of a crane-neck, whereby there is no angle to catch soil and the iron does not get clogged so easily as the end of the wooden handle of the common hoe. Moreover by means of the craning the line of draught by the handle remains as nearly as possible on a level with the edge of the blade, so that the draw is steadier and the implement less easily turned aside. The ridge may be shaped directly with the hand, or with the ridge-mould (Fig. 26), which is made of iron to prevent clogging and just spans the width of a bed. The dimensions of the ridges will depend on the nature of the soil and of the seeds, on the rooting and constitution of the seedlings, and on whether the seed is sown only in a single row along the top or also on the sides. The formation and maintenance of ridges is both troublesome and expensive, and hence, except in very wet localities such as we need scarcely ever select for a permanent nursery, or for the special benefit of some particular species, furrows are to be preferred.

Furrows.—The first point to consider is the dimension of the furrows. Their width will depend on the size of the seed, on the number of the rows of seed sown in each, and on the depth itself of the furrows. In practice it is never advisable to sow more than two rows of seed in the same furrow, whereby the arrangement, in which the seedlings stand in equidistant

pairs of lines, is secured. The depth of the furrows will depend on the size of the seeds, on the length of time required for their germination, on the quantity of manure put in with the seed, and on the necessity or otherwise of earthing up the young plants. The larger the seeds, the thicker will be the covering required. The more protracted the germination, the better must the seeds be protected from drought or cold or birds, and hence the deeper must they be buried.

The regularity of the furrows is easily secured by stretching along each of the two opposite edges of the bed, by means of stakes, a strong line knotted at the required intervals, and then laying a short line or stick across between two opposite knots to guide the tracing of the furrow.

The furrows may be made with the hand alone or with the aid of special draw-hoes, such as the trowel-hoe (Fig. 27) or the share-hoe (Fig. 28). The size of the blade and the angle between the blade and handle will vary with the width and depth of the furrows. Other convenient implements are the sowing wedge and board, in the employment of which no cross guiding line or stick is necessary, as they are just long enough to lie exactly across the beds. The sowing wedge (Fig. 29), held by the two handles, is laid across the bed between two opposite knots and rammed into the soil to the required depth. It is then worked from side to side so as slightly to widen the opening of the furrow and to consolidate its sides, whereby the implement can be taken out without disturbing any portion of the furrow. The wedge is obviously adapted for use only in more or less free soil that does not clog, and it ought to be sponged or mopped each time before it is forced into the soil. When small furrows are required two or more wedges may be secured together by cross battens as shown in Fig. 30. For still smaller seeds the sowing board (Fig. 31) should be used. To the under face of a plank about 1½ inches thick are attached two or three laths at the required distance apart. The under surface of the laths is grooved in the middle along their entire length, so that the bottom of the furrows is given a pronounced convex section, and seeds dropped along the middle or highest line fall uniformly down each side, thus sowing two lines of seed in a single operation. In using the sowing board the trouble of measuring off distances, before it can be placed and pressed down, may be saved by making the board so that it projects

on each side beyond the outer lath to the extent of half the interval required between two furrows. Two boards may then be used side by side, each being moved forward alternately. Similarly, and with the same object, the cross battens in the combined wedge may be lengthened.

The number of seeds to sow will depend, as before, on their size and quality, and on the rapidity of growth of the young plants, their requirements as regards light and shelter, and the time that they are to remain in the seed-bed. Large seeds of good quality should be arranged in a continuous line, touching or almost touching each other. Smaller seeds, since they produce small plants, may be sown more profusely. When it is once known how much seed ought to be sown, the entire quantity to be used should be divided into small equal lots corresponding to small equal divisions of the beds. In no other way can the seeds be uniformly distributed.

Similarly, the depth of sowing will also depend, as before, on the size of the seed, the time it takes to sprout and its exacting nature as regards the conditions necessary for its successful germination.

Seeds may be sown with the hand or with special implements. Large seeds are most easily put into the furrows with the hand. Small seeds also may be sown with the hand, but there is risk of sowing too thickly or of unequal distribution. To minimise this risk very small seed should be previously mixed with finely sifted vegetable mould, or farmyard or any other suitable manure. But for small seeds it is best to use the sowing horn or sowing bottle. The *sowing horn* (Fig. 32) is made of tin and resembles in shape the can used for oiling machinery, except that the extremity of the spout is slit through for some distance, and the gape of the slit is regulated by means of a sliding ring, it being larger the higher up the ring is fixed. The end of the spout may also be removeable and thus allow of the opening being varied without resort to the device just described. The *sowing bottle* (Fig. 33) is a much simpler contrivance and consists of an ordinary wine or spirit bottle covered with a cap of stiff leather open at the extremity. The opening may be made adjustible, but it is better to use different caps for different openings. It is always an advantage to use bottles of clear glass, as the quantity of seed in them at any time can be at once noted without any effort. It is obvious that in both

the horn and bottle the opening of the spout or cap must be adapted to the size of the seed and to the relative quantity to be sown. The capacity of the horn or bottle should bear a definite proportion to the extent of bed or number of furrows to be sown. A further improvement would be to graduate the bottle by means of thin lines scratched into it.

It is always advisable, before sowing, to strew the bottom of the furrows more or less thickly with manure, such as vegetable mould, farmyard manure, surkhi-ash or any mixture of these three, in order to secure a perfect bed for the seed. To the same end the seeds should be covered with the same manure. When the covering of manure has been given, the surface of the bed should be lightly raked over and levelled and the sowing is then complete.

VALUE OF SOWING IN LINES.—The advantages of sowing the seeds in lines are :—

(i) The amount of growing room required by the seedlings is easily and exactly regulated. The roots have free room to develop on each side between the lines, and, however crowded the seedlings may be in each line, they receive light not only from above but also from at least one side. A given area can thus be fully utilised in the happiest manner possible.

(ii) The seedlings give each other mutual support and shelter against frost, sun-stroke, &c.

(iii) The weeding of the beds becomes very easy (see. p. 193).

(iv) The hoeing of the beds is also singularly facilitated (see p. 194.)

(v) The removal of the seedlings never presents any difficulty (see pp. 200.)

(vi) If the seedlings are not to be transplanted for some time, the beds can be thoroughly and evenly manured with ease (see p. 194).

(vii) If, owing to the seeds not being uniformly good, they fail at any points, failures are easily detected and the gaps can be filled up at once without any trouble.

(viii) It is the only method which renders possible the amputation of the tap-root *in situ* (see page 194).

§ 5. *Watering the seed-beds.*

As soon as the sowing is over, the beds should be watered; this even if the soil is moist, as it is the quickest and most effective

way of producing a perfect contact between the soil and the seeds and of thus placing these latter in the best conditions possible for absorbing moisture and completing the process of germination. The flooding system of irrigation should be avoided, for the breaking up of the inevitable superficial crust of fine mud and the simple rush of the water itself would necessarily disarrange the entire seed-bed and uncover many of the seeds, especially if small ones have been sown; and besides this, the flooding water, as it sinks into the lower depths of the soil, must obviously carry away with it, out of reach of the future plants, all the soluble and finer portions of the manure, and the seeds themselves may suffer from being surrounded all at once by an excess of water. In the impracticability of employing the percolation system, it is better to hand-water than to irrigate.

The moisture of the soil must, with only a single exception, be constantly maintained until germination is complete, and the water must, therefore, be given as often as the soil begins to get dry. The exception just referred to applies to the rare case of those seeds, which possess so hard, tough and impermeable a shell, that their germination is promoted by allowing the soil to quite dry up before it is watered again, the porosity and facility to dehisce of the shells being thereby increased. Indeed it may be found expedient to repeat this alternate drenching and drying more than once, as with teak in Central India. In these exceptional cases the watering on each occasion ought to be as copious as possible, and the flooding system of irrigation may then be employed.

After the plants have come up above ground, less frequent watering will be necessary, but, on the other hand, more water will have to be given on each occasion, and handwatering should, as far as can be helped, be entirely given up.

In addition to the above advantages, sowing in furrows offers the signal one of securing, with very little special care, an even distribution and the right depth of sowing for the seeds, however large these may be.

The only disadvantage of sowing in lines as compared with free scattering is that, when the seeds are small, it takes more time; but except when the seeds are to be sown as thickly as possible, the countervailing advantages offer far more than a mere compensation.

§ 6. *Protection of the seed-beds.*

Both the seeds and the young plants are exposed to many causes of injury or destruction, against which they have to be protected.

A Protection against animals

BIRDS.—Many kinds of seeds and the tender shoots of young seedlings are greedily devoured by birds. Scare-crows are of little use, as most birds, especially sparrows, doves, &c., soon get accustomed to them. Rattles, a good and easily made pattern of which is given in Fig. 34, may be set up at different points and all worked simultaneously by means of lines connected with a single one worked from some central post of observation. Automatic rattles, worked by the wind or flowing water, could also be easily put up, and an improvement on this would be to attach the rattles to figures made up like human beings. But the most effective plan would be to arm a man with a gun and a few blank and even loaded cartridges, or to put a strong coop of close bamboo or other trellis work over the beds (Fig. 35), which would also have the advantage of keeping out many other kinds of animals.

HARES AND PORCUPINES.—These animals generally commit their depredations by night and no fence sufficiently economical can keep them out. The only plan is to scare them away with rattles or scarecrows, or to leave one or two small openings by which they may be encouraged to enter rather than at any other point, and there to shoot or trap them as they enter. Coops may also be used.

SQUIRRELS.—Squirrels can be kept off only by constant watching and moving about. For beds, in which the seedlings are still small or the seeds have not yet germinated, coops will answer perfectly.

RATS, MICE AND MOLES.—Most of these are burrowing animals. Moles are sometimes very useful, as they feed on insects and worms, but they undermine the beds and thus cause destruction to both seeds and seedlings. When numerous, they should be trapped or poisoned, but they are fortunately confined only to the Himalayan region. Rats and mice do damage sometimes by eating the seeds, sometimes by nibbling round and at the roots of the young plants. They may often be successfully caught in ordinary half-burnt water pots (*gharás*), let into the ground and half full of water, and with their mouths concealed with a thin covering of grass. But the

most effective plan is to poison them. Grains of wheat specially prepared with strychine, or large pills of flour containing strychnine, arsenic or phosphorus, should be put into drain-tiles placed underground or on the beds at various points.

MONKEYS.—These pests can be kept at a distance only by shooting one or two as often as they approach the nursery.

INSECTS AND SPIDERS.—Seeds and all parts of plants are liable to the attacks of insects.

Seeds that have a protracted germination necessarily suffer most. Seeds liable to be attacked should be sown in surkhi-ash and their sojourn in the soil shortened by some forcing process. Ash should also be sprinkled over the bed. Soaking the seeds in a solution of camphor, besides hastening germination, also preserves them from the attacks of insects.

Grubs of beetles gnaw roots, their presence being betrayed by the sudden withering up of a seedling here and a seedling there. They must be picked out of the soil one by one. Some other insects that attack roots live in larger or smaller colonies. The latter are easily destroyed; but white ants are extremely difficult to overcome. The drenching of the soil by means of irrigation often suffices to keep them away. Sprinkling the beds with a weak solution of assafœtida is thoroughly effective. The decomposing juices of some plants, such as the prickly pear (*Opuntia Dillenii*, nim, &c.,) keep white ants at a distance, and their leaves should therefore be used in sufficient proportion in preparing vegetable mould, or rotted in a tank or cistern through which the irrigation water has to pass. It is superfluous to add that, where white ants abound, manures which attract them should be avoided.

Those insects which nibble round the root-collum, near which, when not feeding, they lie concealed in the ground, should be dug out and destroyed.

Insects which attack green herbaceous parts must be picked or brushed off one by one and killed. The brush represented in Fig. 36 may often be found convenient for the purpose.

Spiders suck the juices of plants or injure their foliage with the webs they weave. They are easily destroyed.

Many birds, especially the family of starlings (chief among them the maina, which digs out insects from the soil) and thrushes

prey upon insects. Such birds ought to be encouraged by giving them every facility for nidification. Shrews and lizards also are very useful enemies of insects.

B. Protection against frost.

North of a line passing from Broach through Nassik, Aurangabad, Chanda and Raipur and west of its continuation through Hazaribagh, Patna and Muzaffarpur night frost is one of the greatest enemies the Indian forest nurseryman has to contend against. The simplest and cheapest plan is to fix thatch tatties over the seedlings (Fig. 37, a). But if the frosts are severe, a similar tatty (Fig 37, b) should also be placed edgewise along the south-east side of each bed so as to keep the morning sun off the plants. It is superfluous to say that all these tatties should be light and moveable, and should be taken off every morning as soon as the air has again become warm and the frost has completely disappeared, being put up again about an hour before night-fall. Where the dhádu or wind from the Himalayan snows blows, a tatty should be put up, during its prevalence, on the north side of each bed,

Another plan is to stick twigs and small branches in the ground between the lines. If the cold is not severe, these twigs and branches, if they do not altogether keep out frost, at least mitigate it and prevent a too rapid thaw, and they also have the advantage of not stopping the formation of dew on the plants and in the upper layers of the soil.

A third plan is to place over the beds the wooden trellis frames already described (Fig 35), which temper frost and the morning sun and allow the plants to get the benefit of the nightly dews. As they do not prevent sufficient light and heat from reaching the plants, they need not be removed in the day time like the grass tatties. Bamboo trellis work fixed on supports would be the cheapest form of such cover. In case of severe frost loose grass or a cheap mat could be spread over the trellis work.

A fourth plan is to cover the ground between the lines with a thick layer of straw, which keeps in the heat of the soil and preserves the roots and lower, and generally most sensitive, parts of the stem. The base of the seedlings can be further protected by earthing it up with the aid of the crane-necked (Fig 25) or share (Fig 28) hoes.

A fifth plan, which may be adopted simultaneously with any of the preceding, is to maintain a smouldering fire on the windward

side of each bed. Dry, powdered cattle dung, laid in a narrow deep trench running parallel to, and just outside, the edge of each bed, burns steadily and slowly, requires no watching at all, and gives out the required amount of heat.

Lastly, to minimise the danger from night-frosts, the vegetation of the seedlings should be kept back as much as possible during winter by stopping watering or reducing it to the minimum necessary to keep the plants alive.

C. Protection against excessive insolation.

Excessive heat may retard the functions of nutrition, or, by overheating active and sensitive tissues, disorganise and kill them; while too intense sun light may produce over-transpiration and thus either weaken temporarily or hurt permanently the seedlings. In order to keep the temperature as near the optimum as possible and to prevent transpiration in excess of the moisture taken up by the roots, we must temper the rays of the sun by shading the beds with tatties, mats, thatch, or more or less open trellis-work; and also, by keeping the soil sufficiently moist and, if necessary, also by covering it over with straw, prevent it from becoming overheated. It is the afternoon sun from which the beds are chiefly to be shaded. Another plan is to grow along the western edge of each bed a line of persistent agricultural plants, such as castor oil, cotton, croton, &c., which at least pay for their maintenance without interfering with the roots of the seedlings. Lucerne, which is a soil-improving crop, may also be sown in lines alternating with the lines of seedlings.

The most sensitive part of the seedlings, the region of the root-collum, should be earthed up where the heat of the sun or hot winds are to be feared. Covering the beds with straw or growing alternate lines of lucerne also affords the necessary protection; but earthing up always yields the best results, as, by withdrawing the buds at the root-collum from the influence of light, it guarantees their preservation and assists them to become dormant, thereby insuring the vitality of the future transplants. The earthing up may be effected with the crane-necked (Fig 25) or share (Fig 28) hoes.

§ 7.—*Weeding and maintenance of a loose rich soil.*

Weeds amongst the seedlings not only live at the expense of the nutritive matters in the soil intended for the seedlings, but also, owing to their usually greater vigour, directly injure the roots and foliage of the seedlings. Any weeds coming up should be forthwith removed by the roots so as to prevent them from growing up

again, and nowhere near the seed beds should weeds be kept long enough to run to seed. All woody growth, which in newly broken up forest land, be it never so carefully prepared, will not unfrequently come up at numerous points, should be grubbed out at once along with the deep-seated stool, root or rhizome producing it. Stray weeds springing up here and there must of course be plucked up individually; otherwise it is always advisable to combine the weeding with the operation next to be described.

The soil in the seed-beds will always gradually settle and become caked, and will, therefore, require to be worked up from time to time so as always to keep it loose enough to allow of the unchecked aëration of the roots of the seedlings, of the deposition of dew within itself, and of the undiminished action of other beneficial weather influences in its interior. This periodical loosening of the soil may be effected with various implements. If the sowing has been done broadcast and the seedlings stand close together, the common garden trowel (Fig. 38), or the Indian khurpa (Fig. 39) are the only implements that can be used. Otherwise pickforks (Fig. 40), drags (pickforks *minus* the mattock end, but much lighter; see also Fig. 41), iron rakes (Figures 42-44), garden forks (Fig. 45-47), or the share-hoe (Fig. 28) should be employed according to circumstances.

If the seedlings are kept for any length of time in the beds, the soil may become exhausted and require to be manured again. Advantage should be taken of the operation just described to put in the fresh manure.

§ 8.—*Amputation of the taproot.*

If the seedlings are allowed to remain for any considerable period in the seed-beds and are to be put out directly thence into the forest, it is evident that the curtailment of their taproot to the length required and the formation of a sufficiently bushy mass of rootlets and root-hairs becomes necessary, for otherwise the lifting up of the seedlings would be difficult, a very considerable part of their root apparatus would be either injured or left behind in the soil, and their success out in the forest would in most cases be rendered extremely doubtful. The curtailment of the taproot necessarily induces the development of a compendious, bushy mass of rootlets and root-fibres, thanks to which the seedlings can be extracted, transported and finally put out in the forest with ease and comparative safety.

Where, as described above on page 170, a special floor, impenetrable to roots, has been formed at the requisite depth for each seed-bed, the shortening of the tap-root and the consequent development of side-roots takes place naturally. But where, for any reasons, no such floor has been prepared, the tap-root must be artificially shortened As it is a necessary condition that the seedlings in a seed-bed shall not be removed for this operation (for otherwise we should have a true case of transplanting into nursery lines), the tap-roots have to be amputated *in situ.* This may be done with a spade having a thin, flat blade and a sharp oblique cutting edge (Fig. 48): a square edge might, as the soil is always loose, only push away the roots without going through them. This amputation should be effected only after the tap root has become sufficiently lignified and before it has become too strong to render the removal of so much of its lower portion injurious to the seedlings. Another plan is to expose, on one side, the roots of a line of seedlings, and then to cut off the tap-roots with a sharp pruning knife; but this method is obviously so laborious that it would be better to go in at once for transplanting into nursery lines, which would be not only less tedious and expensive, but more effective.

The amputation of the tap-root injures the seedlings of many species, notably those which form a stout radish-like tap-root, like teak, sal, &c. The pines and firs also suffer from the curtailment of their tap-roots, as the section, being at once covered over with a secretion of resin, cannot absorb nourishment from the soil. And so the operation should be avoided, whenever possible, by putting out the seedlings young or transplanting them early into nursery lines.

§ 4. *Training of the plants.*

As the seedlings raised in seed-beds are usually young and small, we are seldom called upon to train them to develop in a particular way. Hence nothing special need be said here on the subject and the student is referred to page 201, under Nursery Lines.

ARTICLE 9.

PREPARATION AND MANAGEMENT OF NURSERY LINES.

Before the student can study the actual preparation and management of nursery lines, he must understand fully why and under what circumstances transplants from the seed-beds must often undergo a further training or schooling before being allowed to leave the nursery.

He must also remember that the planting material raised in nursery lines comprises, besides seedlings, also suckers, rhizomes and rhizome-shoots, slips and cuttings, layers, and grafted and budded plants; and that the seedlings may be self-sown plants from the forest as well as those obtained from the nursery seedbeds.

§ 1. *Nursery lines and seed-beds compared.*

The use of nursery lines should be limited to cases of inevitable necessity. As compared with seed-beds they offer the following characteristics :—

(i) They require a much larger area of prepared ground ;

(ii) Hence there is greater waste of manure, and

(iii) More water is required and the arrangements for watering are proportionately much more extensive and elaborate ;

(iv) The seedlings standing far apart, the soil deteriorates more rapidly ;

(v) For the same reason weeds are more abundant and give proportionately more trouble to remove them ;

(vi) The plants require more individual attention ;

(vii) Greater skill and care are called for ;

(viii) Control and management are much more difficult ;

(ix) The seedlings being larger, their lifting up and transport to the forest are more difficult and require more labour and carriage ; and,

(x) As a consequence of all the preceding characters, they are much more costly.

Hence nursery lines should be resorted to only when it is necessary to raise material—

1. For planting out in avenues, groves, parks and hedgerows.
2. For planting up pasture lands.
3. For planting in places exposed to climatic extremes.
4. For planting in rich soil liable to be overrun with large strong weeds, and especially grasses possessing deep, abundant, powerful and vivacious roots and rhizomes.
5. For planting in localities subject to inundations.
6. For planting in the midst of advanced growth that has already reached a certain size.
7. For introducing new seedling growth in a coppice.

For all the above purposes large plants, such as cannot be produced in seed-beds, are required. In every other case seedbed-raised plants suffice.

Seedlings may require being schooled in nursery lines in yet two other cases, viz. (i) when, by reason of the supply exceeding the demand, they have been kept so long in the seed-bed that they must be pricked out in order to acquire the proper root-development; and (ii) when, for any reason, self-sown seedlings from the forest are to be used, and owing to the unfavourable soil of the forest, the root-development of the young plants is defective.

§ 2. *The schooling of seedlings.*

By far the largest proportion of planting material raised in forest nurseries consists of seedlings. We will, therefore, first of all describe in detail the management of seedlings in nursery lines. Much of the procedure described will be common to the treatment of root suckers, rhizomes, slips and cuttings, and layers and grafts, and our remarks regarding those exceptional classes of transplants will be brief and of purely special application.

In dealing with the schooling of seedlings the following points will be noticed:—(A) Age of transplanting and number of times to transplant; (B) season for transplanting; (C) distance of transplanting; (D) preparation of the soil; (E) lifting up of the seedlings; (F) method of transplanting; (G) watering; (H) protection (I) weeding and hoeing; and (J) training.

A. Age for first transplanting and number of times to transplant.

The age at which seedlings should be removed from the seed beds to nursery lines will obviously depend on—

(i) The nature of the species;

(ii) The crowded state of the seedlings in the seed beds;

(iii) The rapidity of growth of the seedlings at the time in question;

(iv) The year in which the seedlings are to be put out and

(v) The number of times the seedlings are to be transplanted.

Under no circumstances, however, should seedlings leave the seed bed before lignification of the tap or main roots and the stem is at least fairly well advanced: for the roots cannot but be more or less injured or weakened by their removal, and the presence of wood-fibres is therefore absolutely necessary to conduct water from the roots to the leaves rapidly enough to keep pace with the inevitable loss by transpiration.

As the chief object of transplanting is to keep the roots of the seedlings, however large these may be, within manageable limits, it is evident that if the interval between the first transplanting

and the time when the seedlings are to be put out is so long that the roots are bound in the meanwhile to spread out too far in every direction, a second transplanting must take place. And indeed, if the interval is long enough, a third and even a fourth transplanting may become necessary. But, as a rule, it is seldom that a second transplanting is required; and the necessity of a third, and *à fortiori* a fourth, transplanting is altogether exceptional.

The interval between two transplantings will depend—

(i) On the rapidity of growth of the plants above ground,

(ii) On the natural tendency to spread of their roots, and

(iii) On the ease with which the roots injured in the previous transplanting recover.

The last transplanting will evidently precede the putting out of the seedlings by an interval only just long enough to enable the roots to recover completely without extending too far downwards. In the case of very large seedlings the plan described on page 230 saves a last transplanting.

B. Season for transplanting.

It may be laid down as a general rule that unless special circumstances order otherwise, the best time for transplanting is soon after the reawakening of vegetable activity, for the plants are then best able to recover from any injury they may suffer and they have almost the entire growing season before them during which to establish themselves thoroughly in their new place. For those species which start into activity at the beginning of the summer rains, as, for instance, teak, *Terminalia tomentosa, &c.*, there can be no question as to the most favourable time for transplanting them being soon after the first showers have fallen. This of course presupposes that the seedlings are ready to transplant then.

But it may happen that the seedlings in question are still too small to be removed from the seed bed. In that case, if the cold weather in the locality is always mild, transplanting may be effected as soon as the seedlings are ready, and the seedlings will continue establishing themselves all through the cold weather. Striking new roots, and never suffering from excessive transpiration, they will be strong enough to live through the ensuing hot weather, and will be then ready to make a full start at the beginning of the following rains. In most parts of India where frosts are unknown, there are also regular cold weather rains. Where such cold weather rains occur, they are an additional justification for autumn transplanting.

Another obvious exception to the general rule enunciated at the beginning of this article is that of species which, like sal, sissu and most of the hill trees, start into vegetable activity in spring. In their case it is evident that transplanting in that season is not to be recommended, since in the plains the hot weather immediately follows, while in the hills May and June are certainly not favourable months for the recovery of seedlings that have received any injury to their roots, the soil being then too cold for root activity, while the sun and air are sufficiently warm for rapid transpiration. Hence the beginning of the rains seems to be the most suitable time for transplanting such species.

C. Distance of transplanting.

If the plants are small, the distance between them in the lines should be less than that between the lines themselves. If plants six feet in height and upwards are required, then it is best to let the two intervals be equal.

The distance between the lines, as well as between the plants in each line, will necessarily depend on the size of transplants required, on their size when pricked out, on the rapidity of their growth, and on the special habits and requirements of the species. With our hundreds of species and the great variety of conditions of climate, soil and locality prevailing in India, it is evident that no hard and fast rule can be laid down on the subject, either for all species in general or for any one species in particular. Two main points must, however, always be borne in mind: (1) that the plants should never be allowed to become so crowded as to be unable to develop a full vigorous crown, and (2) that they should never be put in so far apart as to be unable to shelter the soil and afford each other mutual protection. Another consequence of putting the plants down too far apart is either waste of valuable space or encouragement for them to spread out their roots unduly. The best corrective against the latter defect is, after close transplanting, a loose rich soil in which the seedlings can nourish themselves within the smallest possible compass.

D. Preparation of the soil.

Whatever otherwise their disposition, the nursery lines should be straight and parallel, otherwise irrigation would become very troublesome or wasteful, and weeding and supervision extremaly difficult.

If the seedlings required are not large, then a group of nursery lines may, and usually does, assume simply the form of a seed-bed and are prepared like them, the only difference being that in the one case we sow seeds, in the other we put in seedlings. Indeed the seed-beds themselves may be directly converted into nursery lines by simply removing every alternate line of seedlings and thinning out the seedlings in each line that is left, so as to have a distinct interval between two consecutive seedlings. A further step in differentiation would be, if the interval between two consecutive lines exceeded twelve inches, to open a trench between the lines of the same depth as the distributing channels and to serve the same purpose as these last. As long as each plot of plants resembles a seed-bed in general appearance, the soil is prepared in exactly the same way as for seed-beds, except of course when the seed-beds themselves are immediately converted into nursery lines by the removal of alternate lines and intermediate seedlings. In the latter case, the removal itself of the seedlings sufficiently loosens the soil and clears it of weeds, and manure can be given in relevelling it.

But when the plants are so large that they require to stand at least 18 inches apart both ways, then it is obvious that the seed-bed form would lead to a considerable waste of manure and labour, since the soil need be carefully prepared only immediately round each seedling. Under these circumstances the general preparation of the soil as described in Article 5, pp. 165-172 is all that is required, the further improvement of the soil, in which each seedling is actually to stand, being effected only at the time of transplanting and more or less as a consequence of that operation.

E. Lifting up of the seedlings.

If the plants are small, a simple way to take them up is to push a khurpa or, better still, the common trowel under them and lift them up on it. This is the best method to use in seed-beds that have been sown broad-cast: it lifts up the seedlings with earth round the roots, it is very expeditious, and may be employed in any kind of soil, whether the seedlings are growing isolated or in groups or lines.

With larger seedlings, the roots of which have attained a certain development both sideways and downwards, the employment of the khurpa or trowel is out of the question. If the seedlings are standing isolated, the conical transplanter (Fig. 49) is very suitable in soil that does not clog. The semicircular transplanter (Fig. 50) may be

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used in any soil. Both the above implements are adapted for taking up seedlings with soil round the roots, while the first possesses the additional advantage, owing to its conical form, of lifting up the seedling with its ball of earth at once, and of equally rapidly making a hole of the exact width and depth to receive the seedling in its new place. But if the seedlings stand in lines, by far the best plan is to open a trench of sufficient depth along the outside of one of the extreme lines and, with a flat spade or hoe inserted into the ground on the other side of the line, to tilt over the seedlings, with the soil in which they are standing, into the trench. The next line of seedlings can then be similarly tilted over into the trench produced by the removal of the first line, and so on. If it is desired to maintain the roots covered, the nurseryman has only to take out each plant with the soil adhering thereto. Otherwise he can pick out the plants one by one or several together; and then, as in the process of being tilted over it has already got thoroughly loosened, the soil can easily be brushed or shaken off without injury to the roots.

If the plants are very large and stand well apart, then none of the methods hitherto described will answer and the seedlings will have to be taken out with a curved or flat spade (Figs. 51 and 52), forced into the ground on three or four sides of each plant. Or an ordinary hoe or pick or any other implement may be used.

Whatever method is employed, the least possible damage must be done to the roots, and this the more, the more sensitive the plants are to injuries in their root portion. Under any circumstances, the cheapest method compatible with the safety of the seedlings should be employed.

F. Transplanting.

If the plants are very small, they can be pricked out with the finger or a stake, knotted lines being used, as in sowing, to guide the nurseryman. If they are larger, the best plan is to put them into furrows made with implements similar to, but in some cases slightly larger than, those described under the head of sowing (Figs. 27, 28 and 29), or with the common hoe or spade. The furrows will necessarily be much deeper than those used for sowing. To facilitate the distribution and setting out of the transplants in the lines, the planting batten (Fig. 53) should be used. The batten, which should be rather longer than the width of the planting bed, is placed longitudinally over a furrow, with its two ends resting on the soil beyond, and a plant is inserted into each

nick, where it is then naturally held in position. The nurseryman has thus both hands free to arrange the roots and fill up the furrow. As soon as the furrow is filled up, the batten is moved away to the next one. When the furrows are made with hoes or spades, each furrow should be filled up with the soil taken out in making the succeeding one, a device that saves much time. Plants of some size are best put into the middle of the furrows, as their roots require to be spread out before the soil is filled in; smaller plants, possessing chiefly a single main root, may be put up against one side of the furrow, which side on that account is with advantage made more or less vertical.

If the transplants are so large that furrows cannot be easily or cheaply made for them, then they should be put into pits. Such are the plants that cannot be pricked out in lines forming rectangular groups resembling seed-beds. The pits should be rather larger and deeper than would just suffice to hold the roots of a seedling. They may be prepared with the conical or semicircular transplanter (Figs. 49 and 50), or with curved or flat spades (Figs. 51 and 52), or with the common khurpa (Fig. 39) or trowel (Fig. 38), or with an ordinary hoe. The conical transplanter used should be of the same size as that with which the seedlings to be pricked out were taken up; the earth round the roots comes up as a cylinder of the same diameter as the lower and narrower opening of the implement, while the hole formed with it has the same conical outline as the outer surface of the blade. When other implements are used, the pits should be made somewhat larger than what would just suffice for the full spread of the roots or the ball of earth containing them.

Before the plants are put into the holes or furrows, they may have to be pruned. All broken roots should be cut with a clean section with a sharp knife. Similarly, long roots that require curtailment should be cut down to the required length. Dead, dying or languishing twigs should be removed, and the foliage should, in most cases, be reduced so as to restore as far as possible equilibrium between the diminished root-apparatus and the transpiring surface. It is better that the roots should preponderate over the green parts than that these parts should be in excess of the roots, since in the former case the development of some of the buds will at once restore the desired equilibrium, while in the latter the insufficiency of the roots must debilitate the entire crown. As it is impossible to secure exact equilibrium, it is

advisable to thin the crown a little severely, especially when broad-leaved species are concerned. In doing this, the languishing or less lignified shoots and twigs and half-developed herbaceous leaves should be removed in preference to all others, as they would be the first to suffer from over-transpiration. In the case of conifers the leading shoot should as a rule be carefully preserved.

There is another reason, besides the diminished absorptive power of the roots, for reducing the leaf-surface, and that is that the very fact of the seedlings being removed from their original place, where whey were more or less crowded, to a more free and open situation, accelerates transpiration in a very remarkable manner.

Whether we transplant into furrows or pits, good manure should be strewn thickly over the bottoms of the furrows or pits and also placed at every other point in immediate contact with the roots; and the soil, before it is put back over the roots, should be mixed with a little manure.

After the plants have been put in and the furrows or pits filled up, the soil should be carefully pressed down round the seedlings, so as to ensure a more or less close contact between it and the roots, and to further this end water should be given without delay. Unless the soil is pressed in at once, it will afterwards settle down of itself and leave bare the upper portion of the roots, or, at any rate, the usually sensitive region of the root collum; and besides this, evaporation from the roots will go on in the air-spaces surrounding them and thus endanger their vitality or permanently diminish their absorptive power, or at least prevent them from taking up moisture at once to the full extent of their capability, thereby throwing them back.

G. Watering.

As already directed, the first watering should be given as soon as the planting is over. As the transplants have necessarily lost a part, very often a considerable part, of their root apparatus, the total absorptive power of this latter has consequently been appreciably diminished, and on this account a sufficient degree of moisture in the soil must be constantly maintained until new roots have been produced and the plants have completely regained their vigour. Water must therefore be given frequently, but in small quantities at a time, so as not to deluge the weakened roots. When the plants have fully recovered, the frequency of the watering may he diminished, even to the extent of allowing the surface soil to become more or less dry during the intervals. The larger

and stronger the seedlings are, the less frequently will they require to be watered.

Nursery lines prepared in the form of seed-beds are best watered by the percolation system of irrigation. When the seedlings are large and stand far apart and the seed-bed form is no longer practicable, then the flooding system is the only possible method of irrigating. It may be carried out in one of two ways, either by dividing the whole area of the nursery lines, by means of little ridges, into small compartments, or by making a hollow round each plant and connecting the hollows of a single line with one another by a short channel. By the former plan all the plants of a compartment are watered simultaneously and the entire area is irrigated, whereas by the latter the plants in the several lines are watered in succession one by one and only the soil immediately round each plant is irrigated. This latter plan should be adopted only in the exceptional case of the plants standing far apart and of the necessity of economising a naturally limited water supply.

H. Protection.

AGAINST ANIMALS.—Birds, as a rule, do little damage to seedlings of the size standing in nursery lines, and special precautions need therefore seldom be taken to keep them out. Perhaps parrots, which bite off the leaves and buds of many species, are alone to be guarded against. The larger seedlings may also be injured by birds perching on them.

Hares may nibble off the tender shoots of transplants up to more than a foot high, while against porcupines the size of the seedlings is never any protection. Both animals must be kept out as suggested on page 190.

Rats, monkeys, insects and spiders are as much to be dreaded here as in seed-beds. The measures to be taken against them are the same as those described on pp. 190-191.

AGAINST FROST.—For the smaller transplants the same precautions must be taken as for plants in seed-beds (*vide* pp. 192-193.) But when the plants are large, and therefore stand far apart and occupy a large area of ground, covering with thatch, &c., is out of the question. Next to selecting ground not exposed to severe frosts, the only plan is to shelter them with tall growth of some hardy agricutural plant that requires little from the soil and at least covers the cost of cultivation. If the frosts are not severe, it will suffice to bind the stems and branches loosely with dry grass or straw.

AGAINST EXCESSIVE INSOLATION AND HOT WINDS.—Immediately after the seedlings have been transplanted and until they have begun to strike new roots, they should, whenever practicable, be shaded from the sun to prevent transpiration in excess of the limited supply of moisture absorbed by their diminished root-apparatus. If the plants are too large to be shaded at a reasonable cost, a part of their foliage or transpiring surface should be removed, as already recommended on p. 201.

After the plants have struck, they have nothing to fear from the sun's light and little from its heat so long as they are sufficiently watered The larger the transplants, the less can they be injured by heat. As a rule, the portion of a transplant most sensitive to the sun's rays and hot dry winds is the region of the root-collum: this may be protected by drawing earth over it. Stems with tender bark may be protected by tying grass or straw loosely round them.

I. Weeding and maintenance of a loose rich soil.

Nursery lines forming groups resembling seed-beds should be weeded in the same way as the latter (see pp. 193-4). Otherwise the same constant careful tending should be given only to the immediate vicinity of the seedlings, the ground between the lines being simply hoed up from time to time, the interval between one hoeing and the next being only just short enough to prevent the soil from becoming caked or weeds difficult to kill from gaining possession of the soil.

J. Training the transplants.

However carefully the transplants may be raised, some amongst them will always assume an abnormal or irregular development, or sicken without however dying. These must be trained into well-shaped, vigorous, healthy seedlings by means of judicious pruning or by altogether cutting them back.

A. Pruning.

As every deprivation of a part of its foliage results in a corresponding temporary curtailment of the vegetative vigour of a plant, pruning should be resorted to only in the four following cases:—

(i) The end of the leading shoot may have been damaged or weakened by frost or other causes beyond hope of recovery. The weak or damaged portion should be removed immediately above a strong and healthy bud, which will thereby be encouraged to develop and replace the lost leading shoot. If the phyllotaxis is opposite or whorled, there will be more than one bud immediately

under the section. It is not always possible to recognise which of these buds is the strongest, nor can it be affirmed with certainty that any given bud will sprout and come to some good. Hence it is sometimes advisable to let every one of the buds develop, and get rid of all but one only when it is quite clear which is likely to make the best leading-shoot. In most cases this takes place before the buds have attained any development, and then it will suffice simply to nip off with the fingers the shoots that are to be got rid of.

(ii) Sometimes the lateral shoots of the seedlings become abnormally vigorous at the expense of the leader. These shoots should obviously be weakened by being shortened. The extent of the shortening will depend on their vigour. Very strong shoots will have to be reduced to half their length, but if the operation is done in time, simply nipping off the terminal bud, or breaking off the two or three extreme internodes, will secure the end sought.

(iii) Sometimes, owing to circumstances beyond control, a fork has been produced, by which the vigour of the crown is divided between two shoots. We must get rid of that one of the two, which is less promising, either because it is weaker or less well lignified or growing more decidedly out of the straight line.

(iv) Instead of a distinct single leader we may have a number of shoots growing up in the form of a broom. This is only an exaggerated forking and should be either treated on the same principles as the fork if one of the shoots is strong enough to become the leader, or a new leader must be formed by pruning down to the first vigorous bud below this defective growth, as in the first case.

B. Cutting back.

This wholesale remedy should be adopted only in the last resort, and should, therefore, be restricted to the three cases given below. It is evident that only broad-leaved species can benefit by it.

(i) Sometimes seedlings have a tendency to grow tall and lanky, with a narrow spare crown. This tendency can only be corrected by cutting back the seedlings in question. The new shoots that come up do not generally have the same defect as the original ones. The formation of a brush of shoots should be avoided by nipping off the weaker shoots as they show themselves.

(ii) In some seedlings the bark of the stem, and often of other parts also, becomes tough and dry and the cambium becomes inactive and unable to exercise tension enough to split the unyielding bark; in other words, the seedlings become hide-bound. Here again the sole remedy is cutting back and absolute renewal of the entire portion of the seedlings above ground.

(iii) Occasionally stronger plants can be produced by cutting back the original seedlings, and the plants thus produced have, for obvious reasons, their numerous small roots close to the surface, a very desirable quality indeed.

§ 3.—*The schooling of root-suckers.*

Either (A) suckers already produced may be put down in the lines, or (B) only cuttings of roots of species that throw up suckers.

TRUE SUCKERS.—The best suckers to use are such as have sprung up on small roots and have already developed some roots of their own; they then approach nearest in character to seedlings. The portion of the parent root removed with the sucker should be cut with a clean oblique section at both ends to facilitate the absorption of water. Although every part of the stem and of the main roots of a sucker is always thoroughly lignified and is hence able to conduct water rapidly, still it is advisable to reduce, by judicious trimming, the foliage of the sucker in order to prevent any chance of excessive transpiration. The suckers should be put down in the same manner and with the same care as seedlings of their own size.

ROOT-CUTTINGS.—These are short sections, from a few inches to a foot long, of roots not more than an inch thick. They should be taken in preference from knotty or otherwise irregularly shaped roots, as they are then more likely to be successful and to send up strong shoots. They ought to be inserted in the soil obliquely at an angle of about 60°, with their upper extremity just below the surface of the soil, which should be loose and rich and always kept in a more or less saturated condition. Both ends should be cut clean and obliquely. Rootlets and root-fibres should be preserved, only ragged ends and wounded portions being removed with a clean cut.

GENERAL REMARKS.—Plants raised from suckers generally exaggerate the original tendency of the species, to which they belong, to produce suckers; and on that account, while they may be well adapted for covering up bare land or forming a hedge rapidly, they cannot produce as tall, regular and sound timber as seedling trees. Hence propagation by suckers is of extremely rare occurrence in forest nurseries, and this all the more for the additional reason that it succeeds, in the cases in which its adoption is to be recommended, quite or almost as well without any preliminary schooling in a nursery.

The fruit and flower gardener often finds the method of propagation by suckers a useful means of perpetuating good varieties.

§ 4.—*Rhizome shoots.*

Propagation by means of such shoots is a kind of propagation by *division*, that is to say the various rhizomes, with their shoots if any, which form a single bamboo clump, are parted and put down again separately. It is thus an excellent method of increasing the stock of bamboos in a nursery. It is also used, when seed is not available, to raise transplants from clumps growing in the forest; but this practice is subject to the drawback, often serious, of the propagated plants seeding and dying off at the same time as the parent clumps. To minimise this drawback, the rhizomes should be obtained from the youngest clumps available. The simple rhizome, the success of which is, however, never certain, and which should on that account seldom be used except on a small scale, may be put into the ground in the same manner as root-cuttings. But if the leafy stem has developed, the whole should be treated exactly like seedlings of the same size, except that when the stem is thick, say about ½ inch or upwards in diameter, it should be cut down to the top of the second or third internode. This amputation is necessary to prevent the excessive transpiration that would otherwise inevitably follow from the diminished absorption of moisture due to the loss of the greater portion of the root fibres, and the disconnection of the rhizome from the rest of the clump.

§ 5.—*Cuttings.*

Cuttings are used only for propagating species that do not seed or for obtaining at once plants of some size. Only a comparatively small number of species are able to grow from cuttings.

A cutting strikes and becomes established as quickly as transplanted seedlings, and often sooner and even very much sooner. Hence, except for propagating rare species or varieties, there is seldom, if ever, any necessity for putting cuttings through a course of nursery training; and it is very much better to put them out at once where they are required. Hence cuttings will find their place only very exceptionally in a forest nursery. Nevertheless a short description of how to propagate by means of them cannot be omitted from an elementary work like this Manual.

Cuttings may be either sections of the stems of some broad-leaved species, or entire culms or sections of culms of the various species of bamboos.

A. Cuttings of broad-leaved species.

The roots which cuttings develop are all adventitious roots, originating some on the callus formed along the edge of the buried

section by the still active cambium, but the majority from under the lenticels. The formation of a large callus may be secured even before the cutting is severed, by removing a ring of bark or tying a ligature at the point at which it is eventually to be cut off; the elaborated sap being for the most part arrested in its descent by the barkless girdle or ligature, a swelling is produced immediately above consisting of young and, therefore, still active woody and cortical tissue. Until roots are produced, cuttings can absorb moisture from the soil only through their buried lower section, which should therefore have as large an area as practicable and be in the best condition possible to let water enter easily. Hence it ought to be cut obliquely and as clean as possible with a sharp knife. The upper extremity of the cutting is best cut straight across to reduce the surface of evaporation, and, in order to create a further obstacle to evaporation, it should be covered over with clay or, better still, with a mixture of clay and cowdung.

Cuttings should be put down obliquely, so that no part of their buried length may be so far away below the surface of the soil as to be unable to receive the full amount of aëration requisite for producing a vigorous development of roots. For the same reason the oblique surface of the section should be so placed as to be directed more or less upwards.

The best time for putting the cuttings into the ground is just before the re-awakening of vegetative activity, when the wood and the bark are still full of reserve material. The larger the amount of this reserve material is, the more abundant and vigorous will be the production of adventitious roots.

In putting the cuttings into the ground, unless the soil is very loose and soft, they should not be forced in, but placed in holes made with a stake or dibber; otherwise there is danger of the bark of the lower extremity being ruptured and forced away from the wood. They should be set, if small, in lines, like small seedlings, if large, like large seedlings; and the soil in which they are put in should be as well prepared as possible.

Cuttings may be divided into three main classes, (a) *unpruned rods*, (b) *pruned rods* and (c) *posts*.

UNPRUNED RODS.—These are young branches, from one to four years old, taken without any selection, and are set in the ground broom-fashion with all their twigs and branchlets intact. It is obvious that such cuttings, once they have struck root, cannot be

easily taken up again, and for this reason they are hardly suited for nursery purposes.

PRUNED RODS.—These are sections of from one to three-year-old wood, which are carefully selected and cut from amongst the strongest shoots of the parent plant. The upper extremity of the shoot, being always insufficiently lignified, is removed, and all the twigs and leaves are pruned off. The upper end of each rod should bear two or three vigorous buds, and, in putting the rod into the ground, it is best to leave only these buds above the surface.

Pruned rods are *par excellence* the cuttings to be used in nurseries; and even then, the smaller they are, the better.

POSTS.—These are stout branches from one and a half to three, four and even five inches in diameter, and from five feet to sixteen feet long. It is evident that they are unsuited for use in nurseries, save in the very exceptional case of a very rare species being required to be propagated.

B. Culms.

Culms may be used whole or cut up into sections, and they may be completely buried or have one or two nodes above ground. A crown of adventitious roots springs up at the nodes and the bud at each node forms a leafy shoot. The lower nodes strike best, and indeed those situated in the upper half of the culm never strike if the culm is cut up into sections. Culms are most successfully used at the beginning of their second year of growth; in their first year they are never sufficiently lignified, and do not contain as much reserve constructive materials as they do afterwards, while after the second year the original bud at each node has ceased to exist, having developed into leaf and branch, and the tissues have become too hard to be active enough to produce numerous, strong roots.

In putting down the culms, such branches as interfere with their being placed in position should be pruned off; the remainder may be left with all their foliage, as the fibres of the bamboo are rapid conductors of water.

§ 6.—*Layers.*

Layering is scarcely the work of a forest nurseryman, yet in this country he may have a fruit or flower garden attached to his nursery. Moreover the operation may sometimes be utilized out in the forest for covering bare ground round certain spreading shrubs or trees.

Layers may be made to strike root either (1) *in* the ground or (2) in soil contained in a pot, basket, &c. *above* ground (by *circumposition*, as it is called). In the first case, the branches to be layered are bent into the soil (Figs. 54 and 55) and kept *in situ* by means of a stake or peg with a curved head or with a loop of wire buried in the ground, or, if the layers are thin or possess little elasticity, simply with a stone placed over the soil. If the branch is long and very flexible, it may be bent into and out of the ground more than once (*serpentine layering*, Fig. 55). In the other case (Fig. 56), the branch being too far from the ground or too stiff and brittle to be bent down, it more or less retains its position, but soil or compost is carried up to it and in various ways made to surround it where roots are required to push out. The soil may be put into a box, garden-pot or basket, or even be held together merely with a piece of matting or coarse canvass bound with twine. A garden pot, cut some way down on one side before being burnt, will answer, or the branch may be enclosed between the two halves of one and the same pot, the halves closing up against one another except where the hole in the bottom must allow the branch to pass through. The pots, &c. holding the soil are liable to dry up rapidly from the free play of air round them. To counteract this, they should, during dry weather, be covered with moss, straw, &c. and watered by means of a pot suspended vertically above, through a hole in the bottom of which the water drips continually. Whatever the method of layering employed, the early and abundant development of adventitious roots is encouraged by arresting the downward progress of the elaborated sap. This may be done either (i) by means of a ligature, or (ii) by twisting, or (iii) by tongueing or heeling (Fig. 54 *a*), or (iv) by ringing (Fig. 54 *b*), or (v) by splitting the branch through the middle for about 2 inches of its length, or (vi) by cutting one or more notches right through the bark into the wood.

With species that are specially well adapted for this method of propagation the branches may be laid in the ground for a considerable portion of their length. As only the branchlets and twigs on the underside will need to be cut off in order to lay the branch in the soil, the rest will stand out and become each an independent-rooted individual. This procedure may be adopted with bamboos.

The best season for layering is immediately after the first burst of activity at the beginning of the season of vegetation: it is at this time that trees form the largest quantity of constructive materials and at the same time display the greatest amount of activity in developing new organs.

For layering we may use the same age of wood as for propagation by cuttings, but it is obvious that the thinner the branches are, the more flexible will they be. In any case they must be thoroughly lignified.

Since layers are connected with the parent stem as long as they are still unable to nourish themselves, many trees, even conifers, which cannot be grown from cuttings, may be propagated with more or less certainty by means of layers.

§ . *Grafting.*

This is still less the work of a forest nurseryman than layering, but in a backward country like India we may be required to do it outside our regular professional duties.

Success in grafting depends on the complete amalgamation of the cambium of the scion or graft with that of the stock on which it is put; the connection formed must be organic. Once this connection formed, every new layer of wood or bark made by the scion is formed in organic connection with the corresponding layer of wood or bark added by the stock. Besides this, the empty space between the two sections inside the cambium ring may be filled up with new woody cellular tissue formed by the medullary rays and the parenchymatous tissue in the fibro-vascular bundles, and the scion and stock become thereby completely cemented together. Consequently, whatever the method of grafting, the cambium of the scion must be placed in direct and close contact with the cambium of the stock. To facilitate and maintain this contact until the ultimate amalgamation takes place, the lines of junction between the scion and the stock should be covered up and protected against atmospheric influences with variously-made compositions. Indian malis use chiefly clay mixed with cowdung, the object of the cowdung being to prevent cracking, to maintain an even temperature, and the better to preserve moisture. The proportions in the mixture are 1 of cowdung to from 1 to 2 of clay or clayey loam. The addition of a little finely-chopped stiff hay diminishes still further the risk of the clay cracking and falling off. The composition should be

made at least a week before it is used and thorough mixture should be secured by frequent turning and beating with mallets. It should not be allowed to get dry before use. Besides grafting clay there are various preparations of what is called Grafting Wax. Firminger in his "Manual on Gardening in India" gives an excellent recipe for one as follows :—

"Take 27 oz. of common yellow resin and melt it gradually, so as not to drive off the turpentine. When reduced to the thickness of a syrup, add ten ounces of alcohol. Shake them thoroughly together and pour them at once into a well-stoppered bottle. When the graft is inserted and tied in its place with a strand of matting, cover the surface of the whole with this varnish with a small painters' brush. Such varnish is neither affected by heat, cold nor wet."

Grafting clay possesses several decided advantages over grafting wax. Firstly, being put on moist, it can gradually, and therefore with no risk of deluging and injuring the exposed cells, restore to the scion all the moisture it has lost while being worked on the stock. Secondly, being itself capable of being kept moist, it can supply moisture to the scion as long as this latter is still unable to obtain as much as it requires from the stock. Thirdly, it prevents rapid and wide fluctuatious of temperature better than any wax can. Fourthly and lastly, however thickly it may be laid on, soil is a natural preservative of wounded vegetable surfaces. On the other hand, clay cannot always be used in grafting small delicate plants, and, as it is not elastic, unless it is taken off soon after perfect union between scion and stock has taken place, it is likely to prevent, by compression, the stem from increasing in diameter at the line of junction, where this increase is indeed most required.

Grafting is impossible unless the scion and stock are closely related, *i. e.*, are varieties of the same species, or species of the same genera, or genera of the same natural order. The power of coalescence does not extend beyond this last degree of affinity.

Besides this, the species to which the scion and stock belong should be able to attain more or less the same diameter at one and the same age. Any great disparity in this respect generally results in the object itself of the grafting being defeated.

One or more of the following ends may be sought in grafting:— (1) to propagate a variety or species that cannot otherwise be acclimatised; (2) to ensure early fruiting, the age both of the stock and of the individual supplying the scion having each its due influence; (3) to strengthen a weak variety or species by

working it on a vigorous stock; (4) to perpetuate varieties of species that cannot be propagated either by cuttings or by layering; (5) to produce pleasing ocular effects.

Theoretically speaking the best time for grafting is, if the weather is not then too hot and dry, just as the season of vegetation is about to begin: this, firstly, because the wood and bark of both stock and scion then contain the maximum quantity of reserve material; secondly, because the sap being then "down", the scion is less liable to suffer damage and recover more easily from injuries than during the full activity of vegetation; and, thirdly and lastly, because, both stock and graft becoming active immediately after the operation, there is no intervening period, during which the cambium cells on the section may from any cause become inert or at least lose to a greater or less extent their activity. Where there is a true spring, this theoretically best time can be realized. But where the season of vegetation is, as in many parts of India, immediately preceded by hot dry weather that must exercise an injurious influence, the operation must be put off to August or September, when the sap is full of formative material, vegetation still active enough to produce the necessary amalgamation of the stock and graft, and the air moist and generally warm. This latter time is still more favourable, if the winter in the locality is mild. In the hot weather the vegetation of the plants to be used as stocks and to supply the scions should be forced by judicious watering. Exceptionally, grafting, particularly budding, may be performed earlier in the rains.

On the way in which the scion is worked on the stock depends the method of grafting. Hence there are numerous methods, but the following are those which are most generally employed:—(a) Splice Grafting, (b) Tongue or Whip Grafting, (c) Crown Grafting, (d) Cleft Grafting, (e) Saddle Grafting (f) Budding and (g) Inarching or Grafting by Approach. In the first five and the seventh methods the scion almost invariably consists of one year old wood, while in budding, the bud used may be taken off any well formed shoot of the preceding or current season.

A. Splice Grafting.

This is a very simple method. It is very suitable for delicate plants, and, when properly done, seldom fails. The wood of the scion and the stock, where they are to be united, should be of exactly

the same girth and shape, so that the cambiums of both may be in complete contact at every point all round. Figure 57 at once explains the method. After tying the scion and stock together with hemp fibre over a fold of matting, the entire section is covered with clay or wax. In splice-grafting it is often advisable to remove the upper, not yet sufficiently lignified, extremity of the scion.

B. Tongue or Whip Grafting.

This is the most frequently employed method of all. It is the same as the preceding with the addition of a slit or tongue in both scion and stock (Fig 58), whereby the former cannot slip about on the latter and both have a greater length of cambium in contact. Besides this, the scion may be smaller than the stock. If it is smaller, it should be joined on to one side of the stock so as to secure the greatest length of contact between the two cambiums. But it is better to avoid using scions of a smaller size than the stock. The upper extremity of the scion, if insufficiently lignified, must be cut off.

C. Crown Grafting.

This (Fig. 59) is the method generally employed when the stock is much larger and older than the scion or when it is intended to renew headed-down trees. The head of the stock is cut off with a smooth, even section. As regards the scion, a little more than half its thickness is cut out and removed from one side of the lower extremity for about two inches of its length, and the remaining thickness is pared down from inside outwards towards the bark, the result being the formation of a thin wedge of wood with the bark attached and a shoulder by means by which the scion rests on the crown of the stock. To work on the scion, a slit is made in the bark of the stock about three inches long; the bark is then carefully raised on one side and the wedge end of the scion inserted between it and the wood. The bark is at once tied down firmly and the union covered over in the usual way. It is evident that several scions, as many even as five or six, may be thus grafted up on one and the same stock. The raised bark is of little use beyond protecting the scion and securing it in its place. Part of it dies, and, by affording a lurking place for insects and collecting moisture, induces decay. Hence tongue-grafting is to be preferred, even when the stock is very much thicker than the scion, up to say 3 or 5 inches in diameter.

D. Cleft Grafting.

In this method (Fig. 60) the top of the stock is cut off horizontally as in crown grafting, but it is then split or cleft down

the centre to receive one or two scions according to the thickness of the stock. If the scion is of the same diameter as the stock, a certain thickness of it is cut out from each side of its lower extremity for about two inches of its length, and the remaining wood, with the bark on each side of it, is pared down to a fine wedge and inserted into the cleft, which it should fill completely. If the scions are smaller, two can be placed on the same stock, one at each extremity of the cleft. The stock should be split down about 3 inches with a chisel, which is kept in the cleft until the scions have been inserted. On its withdrawal the stock closes firmly upon the scions. The stock should then be carefully tied up and the union and the top of the stock covered over as usual. This method of grafting is very simple and easily executed, and rarely fails; but it favours decomposition in the centre of the stock.

E. Saddle Grafting.

Saddle grafting (Fig. 61) is the inverse of cleft grafting, the apex of the stock being cut in the form of a wedge which exactly fits into a slit cut into the base of the scion. It is evident that the stock and the scion must be of one and the same diameter throughout the entire line of union, a coincidence not easily secured.

F. Budding.

Budding differs from all other methods of grafting in that the scion contains no wood at all, and consists only of a bud with a smaller or larger piece of the bark attached. In budding special knives (Fig. 61, A and B) are used, the lower extremities of the handles of which is made of bone or ivory or some hard flexible wood, and is shaped like the end of a paper knife.

According to the shape of the piece of bark and the mode in which it is worked on the stock, there are four principal methods of budding as follow :—

(i) *T or Ordinary Shield-Budding* (Fig. 63). The piece of bark is in the form of a shield from $\frac{2}{5}$ to $\frac{1}{2}$ inch long and $\frac{1}{8}$ to $\frac{1}{3}$ inch broad. In the bark of the stock, where the bud is to be inserted, a T-shaped incision (*B*) is made, the cross-bar of the T being slightly longer than the width of the shield of bark and the upright bar slightly longer than its length. With the sharpened extremity of the handle of the budding-knife, the bark (*b,b*) is gently lifted away from the wood and the bud-bearing shield is then inserted beneath these lifted edges so that the top of the shield fits accurately up against the bark of

the stock immediately above the cross-bar of the T *(C)*. The overlapping bark *(b b)* is then pressed firmly over the shield, a ligature is tied on as shown at *(D)*, and the entire union is then covered over with grafting wax or ordinary crude resin applied with a brush. The bud must of course remain exposed. The T-shaped incision may be made inverted as represented at E *(Inverted T-budding)*. T-budding is very successful with oranges and roses.

(ii) *Square-Shield Budding* (Fig. 64). Here the piece of bark is cut square, and fits exactly into a square incision in the stock, from which incision the bark has been *entirely* removed. As there is no overlapping bark of the stock to cover and protect the bud-bearing shield and thus hasten the union between the bud and stock, this method is not so certain in its results as the preceding.

(iii) *Flute-Budding* (Fig. 65 A). Very little verbal description of this method is required, as the plate explains it pretty fully. The flute should be taken off a cylinder of wood slightly thicker than the one on which it is to be worked, as it shrinks as soon as it has been taken off and the expansive force of the enclosed woody cylinder has ceased to keep it in a state of tension. A narrow bandage is put over the junction of the barks at *(e)* and a cap of soft adhesive plaster (grafting clay answers very well) is put over the top to exclude weather influences. This method suits walnut and other thick-barked trees.

(iv) *Ring-Budding* (Fig. 65 *B*.) The bud-bearing ring of bark *(r)* is taken off by making two parallel incisions right round the circumference and then a third longitudinal cut between these two incisions permits the piece to be peeled off. The ring of bark from the stock, as that is not to be saved, may be more easily removed by making more than one such longitudinal cut. The piece of bark *(r)* should be taken off a part somewhat thicker than the part of the stock on which it is to be applied, both in order to anticipate the shrinkage referred to under flute-budding and also to prevent any chance of a bad fit. If ultimately found too large, the edges can be pared till they just meet when the piece is brought tightly round. A bandage is put on so as to cover and secure every line of union, and grafting wax or clay is applied wherever required. This method of budding is more easily performed than the preceding one, from which it differs principally by the fact that in it the stock need not be headed down at all and can, therefore, continue its vegetative processes with undiminished vigour and thus contribute an abundance of formative matter to complete the union of the scion with itself.

The best season for any of the preceding modes of budding is when the bark of the stock is gorged with sap and comes away easily from the wood, and the weather is moist and warm. Water should never be allowed to enter and lodge between the bark of the scion and the wood of the stock.

G. Inarching.

This method, which is also known as *grafting by approach*, differs from all the previous methods of grafting in that the scion need never be separated from its own original roots, and even when ultimately separated, is not so parted until complete union with the stock has taken place. Inarching is effected by baring the cambium of the stock and scion at a point on one side of each, then fitting the two closely together by the bared surfaces, and finally securing them in position and protecting the surface of contact by means of a bandage and grafting clay or wax. The stock and the plant inarched upon it may be more or less of one and the same size, or the former may be very much smaller and growing in a pot placed at some height above the ground in the crown of the latter, only a small branch of which can obviously be inarched on to it. The first style of inarching is only suitable for the landscape gardener; the second is useful for propagating useful varieties of species, which, like the mango for instance, cannot be perpetuated by seed or grafted by any method or multiplied by layers or cuttings. After complete union has taken place, the branch or plant inarched may be severed at once from the parent tree or stock; but it is better to gradually diminish its partial dependence on the parent either by cutting through it little by little or by girdling it about ¼ inch below the union, so that while a certain quantity of sap (chiefly crude) will still continue to flow into it, the elaborated sap may be arrested just above the girdle and may result in increased vigour of growth in the region of the union.

In baring the cambium for the purpose of inarching, either the wood need not be touched at all, or a thin slice of wood may be removed with the bark. In Fig. 66 the stock and scion are kept more or less parallel to one another, but they may be crossed one over the other.

SECTION VI.

Temporary Nurseries.

All temporary nurseries possess two essential characteristics. In the first place, they must be situated in the middle of, or close

to, the spot to be planted up; and, in the second place, we raise in them only the number of seedlings that are required to stock or fill up within a given time a given area with a certain few definite species. These two characteristics regulate the establishment and entire course of management of nurseries of this class.

ARTICLE 1.

Choice of Site.

Owing to the first characteristic the selection is confined to a limited area. Within that area we must find the most suitable spot for the purpose in view.

The number of species being necessarily few, and frequently reduced to a single one, the choice of soil presents little difficulty. The soil should possess the average, never the exaggerated, qualities of the soil of the area in which the seedlings are to be used. For instance, if the general character of the soil in that area is sandy, the soil of the nursery must not be a pure sand, but one in which the sandy character predominates less or more, acccording to the prevailing type of soil. Again if a stony element is the rule, the nursery should not be established in the most stony spot to be found within the area. And so on.

As regards locality the most level plot of land should be selected. In the plains it should not be a hollow, but a piece of rising ground in which water cannot lodge, but from which also it does not drain off too easily. In the hills old fields generally offer the best sites. The general configuration, aspect and altitude should, like the soil, approach the happy mean, and all exaggerated characters should be carefully avoided.

To what extent the spot should be open or sheltered by standing trees will depend on the nature of the species to be raised and on the amount of protection required against frost, drought, &c. For some species the site must be entirely open, for others again, at the extreme end of the scale, a more or less full canopy of trees overhead will be required. Between these two extremes there are a great many intermediate degrees depending on the hardihood and light-demanding nature of the species to be raised and on the prevalence of frost, drought and other injurious climatic influences in the locality. When the shelter of trees is indispensable, individuals of middle age with long clean boles and crowns, that have not had time to spread out to any great extent, are the best to have. According to

Heyer it is a fact proved by experience that in Europe broad-leaved trees are better to have over conifer seedlings than conifers themselves, and *vice versâ*. This may be found to be true also in India and is certainly completely borne out by our own experience in this country, and its explanation is to be sought in disparity of root-systems and different requirements of the roots in the soil.

As regards accessibility, it is evident that the nursery should not only be situated as near as practicable to the places to be planted up, but be easily reached, and, if possible, be also accessible to hand-carts or wheel-barrows.

ARTICLE 2.

AREA.

The question of area is one of very easy solution, since we know previously the system of planting to be followed and the exact area for which planting material is required. That area will in every case obviously depend on the rate of cost of carriage, the distance over which the plants may be easily or safely transported, and the percentage of failures that, having regard to the local conditions and the character of the species, may be anticipated. In the hills it will also depend on the range of elevation of the hill-side to be operated upon and the number of distinct forest zones of which it consists: each such zone, being entirely the result of well-marked climatic differences, will require a separate nursery situated inside itself. Thus the area of a temporary nursery may vary from a few square yards to half an acre or more. Where pigs, deer or elephants are numerous, it is advisable not to have nurseries of such a size as to invite their depredations by their conspicuousness. Nevertheless, if any establishment can be located at the nursery, the area may of course be large. Under any circumstances, it should be large enough to be able to produce, for safety's sake, something in excess of estimated requirements.

ARTICLE 3.

FORM OF BOUNDARY.

Owing to the small size and temporary nature of such nurseries, the choice of shape admits of great latitude; but if fencing is necessary, economy will require a regular form—a rectangle or square on level ground, a complete terrace or succession of terraces in the hills.

ARTICLE 4.

FENCING.

Where cattle, deer, pigs or elephants must be kept out, fencing will be indispensable. All that has been said regarding this head under permanent nurseries, applies also here; only it must be remembered that, as the fence is required for only a very limited period, it ought to be as cheap as possible and need not be of a lasting nature. Tight-bound fences find their place here. They may be made of bamboo or other wattling carried on strong wooden posts. But fencing should rather be the exception than the rule.

ARTICLE 5.

WATERING.

In those portions of the Himalayas where there are frequent showers in spring, and under exceptional circumstances elsewhere, watering may be dispensed with; otherwise temporary nurseries, like permanent ones, must be watered. But the watering here need be neither abundant nor frequent and may be limited to simply keeping the seedlings alive. When no running water or tank is close at hand, a kacha well or wells should be sunk, if water be near the surface: every other source failing, the water must be brought from the nearest place available.

The method of watering will depend very much upon whether there is any establishment stationed at, or close to, the nursery. Should such be the case, provided also other facilities exist, irrigation may be adopted; otherwise there is rarely any alternative to hand-watering. But as the area is never large, hand-watering, especially if it is simply limited to keeping the seedlings alive, can at the worst constitute only an insignificant item of cost.

ARTICLE 6.

PREPARATION OF THE SOIL.

All low growth and stony elements should be removed. The former may be collected and fired in small heaps and the ashes scattered over the area to be prepared. As temporary nurseries are, even when not selected under standing trees, usually situated on land traversed by woody roots and their extent is generally very limited, the pick or hoe is in most cases cheaper to use than the plough.

Contrary to what obtains in a permanet nursery, the rule in the case of temporary nurseries is, in breaking up the soil, to turn up the sods so as to bring the lower and poorer layers to the surface. The reason for this seeming contradiction is obvious. In temporary nurseries specially prepared, manures in any appreciable quantity are seldom available, and so the best plan is to let the richer upper layers go down and to bring up to the surface the inferior soil, which can be sufficiently effectively top-dressed with any little manure that may be at hand, or, that failing, with good surface soil brought from the surrounding area. As a further means to the same end, the soil should be broken up in the cold weather so as to expose the deeper layers of the soil, even if it be only for a few months, to the fertilising action of atmospheric influences. If this inferior lower soil were left at the bottom, the seedlings would remain underfed and would fail to develop a full bush of rootlets and root-fibres.

With the preceding qualifications, the directions given for the preparation of the soil in permanent nurseries (p.p. 164-167) should be generally followed.

ARTICLE 7.

LAYING OUT OF BEDS, PATHS, &C.

If only germ plants are required, there is obviously no necessity for dividing off the nursery into beds, paths, &c. The entire area may be sown broadcast or naturally by the trees overhead, as the circumstances of the case may dictate. Otherwise the disposition of the interiôr of a temporary nursery will depend on its area. The area may be so small that the entire nursery consists of only a single bed. When large enough for the purpose, it may be divided off into beds and paths, the beds not being too wide to prevent a boy from reaching the middle without stepping or resting on them, and the paths being from two to three feet broad. It is seldom that transplanting is done in temporary nurseries, but when it cannot be dispensed with, it should be restricted to small plants that may be pricked out into beds resembling seed-beds. Transplanting in the nursery itself can become necessary only in the following cases:—(1) When large seedlings are required in lofty mountain ranges with distinct zones of forest growth; (2) whenever, owing to the supply of seed failing or for any other reason, it is necessary to school natural seedlings obtained from the forest. Transplanting may also be resorted to when water is available in sufficient quantity and for a moderate outlay.

ARTICLE 8.

PREPARATION AND MANAGEMENT OF THE SEED-BEDS AND NURSERY LINES.

The beds are prepared in the same way as in permanent nurseries, but with this exception, that as we usually employ hand watering in temporary nurseries, the level of the beds would generally be neither higher nor lower than that of the surrounding soil; if it were lower, water would lodge over them during the rains, and if higher, there would be risk of drought. Nevertheless if the locality was very damp, the beds would be sufficiently raised to prevent wet feet.

The sowing is executed in exactly the same way as in permanent nurseries, but greater attention should be paid to the quantity of seed sown; the plants should come up thickly enough to assist in keeping down weeds and yet be far enough apart not to become spare and linky. Under a canopy of trees, if only germ seedlings were required, it might suffice to let those trees sow the ground naturally.

In the nursery lines the seedlings ought to stand closer together than they would under similar circumstances do in permanent nurseries, where the more intensive cultivation enables the young plants to acquire a greater lateral development, and the weeds can be removed as soon as they show themselves. The seedlings should be pricked out during favourable weather at the commencement of the summer rains; seldom if ever later, even if the succeeding cold weather be mild, because, in view of the unavoidably insufficient supervision and tending characteristic of this class of nurseries, the seedlings must be placed in the very best conditions possible to take care of themselves. For the same reason the pricking out should be done with great care.

Both in the seed-beds and nursery lines the soil should be drenched as soon as the seeds or plants have been put into the ground.

ARTICLE 9.

MAINTENANCE OPERATIONS.

WEEDING.—Weeding can in no case be dispensed with. Where there is shelter of trees overhead, and neither frost nor drought is to be feared, there the freer the beds are of weeds throughout

the year, the better, and the operation should, therefore, be repeated as often as it is required and the necessary labour and supervision are available. But where frost or drought can do harm, the strongest and really dangerous weeds alone should be kept out at all times, and a complete weeding should be performed only at the commencement of the summer rains with the object of giving the plants growing room when they most require it; otherwise the weeds should be left untouched as a necessary protection for the young plants.

PROTECTION AGAINST ANIMALS.—Cattle, deer, elephants and pigs must be kept out by means of fences (see *Fencing* p. 208). Porcupines, monkeys, and hares cannot be excluded except when there is a resident establishment, but the best thing that can be done is to have small, inconspicuous nurseries. As regards rats, the only resource, when they are numerous, is to poison them and to preserve as much of the weeds as is consistent with the favourable growth of the seedlings, because these animals generally prefer clean ground when they can get it. Plants, whose roots are avoided by rats, might be grown mixed up with the seedlings. Against insects there is absolutely no remedy except to select a sheltered, not too sunny site, and to use manures which tend to keep them at a distance. Birds are little to be feared, unless the nursery is conspicuously large; and then too, as the entire area is generally sown up within a few days, it is easy enough to employ watchers during the short period required for the complete germination of the seeds. Once the seedlings are up and the ground covered, there will be nothing conspicuous to attract the few birds that peck off buds and leaves.

PROTECTION AGAINST FROST.—Where trees overhead afford sufficient shelter, no special measure is obviously necessary. Otherwise the necessary protection is secured by means of thatch placed over the beds and along their eastern edge; and a further precaution would be, as explained under weeding, to preserve weeds throughout the cold weather.

PROTECTION AGAINST EXCESSIVE INSOLATION.—Cover overhead or the proximity of a fringe of tall trees on the south side affords as complete protection as can be obtained by covers of thatch in open unsheltered places. In hot or dry weather the seedlings should be watered from once to four times a month according to the proximity and abundance of water and the necessity for the operation.

AMPUTATION OF THE TAP-ROOT.—As a rule, seedlings raised in temporary nurseries are put out early and therefore require no curtailment of the tap-root in the nursery itself. In the exceptional cases demanding this operation the tap-root may be shortened either *in situ* or at the time of pricking out into nursery lines, in the same manner as has been prescribed for permanent nurseries.

TRAINING.—As regards the training of the seedlings the constant care and watchfulness which the operation requires prevents its adoption any where but where there is a resident trained establishment. It is, therefore, very exceptionally resorted to in temporary nurseries. When it can be carried out, the same rules regulate it as have been given for similar work in permanent nurseries.

CHAPTER III

PRELIMINARY WORKS.

The area to be operated upon may not be in a fit condition to be immediately sown or planted up, and some preliminary works, may, therefore, be called for to render it suitable for the purpose. The soil may be either (1) swampy or too wet, or (2) entirely wanting in cohesion, or (3) situated on a slope and liable to slip or be eroded, or (4) too dry to give any hope of rapid success, or even of success at all, without irrigation.

SECTION I.

Treatment of swampy or water-logged land.

Even species that are naturally found in swampy situations grow all the better for some slight correction of an excess of water. Without a certain amount of root-aëration the absorbing organs of plants cannot form the organic acids wherewith to dissolve, and thereby utilise, the large proportion of essential, but not immediately soluble, matters present in the soil; and without sufficient oxygenation the decomposing organic substances in the soil would yield an injurious quantity of humic and other acids hurtful to plant-growth. It is evident that insufficient sub-surface aëration must prove especially fatal to young seedlings, with their extremely delicate, tender and herbaceous constitution, their very limited root-apparatus, their small size, their restricted transpiring surface so utterly disproportionate to their functional activity, and their slight recuperative power. Hence, as already explained in Part I, the significant scarcity of natural reproduction on water-logged or constantly flooded land. The few seedlings that do ultimately survive are unable to extend their roots into the deeper layers of the soil, and hence suffer both in their growth and health and their stability

ARTICLE 1.

SWAMPINESS, ITS CAUSES AND GENERAL CURE.

Swampiness may be due to one or more of the following causes :—

I. *Flooding by overflow of a stream or the sea.* One or both of two remedies may be adopted :—(1) Throw up a dam to keep out the water, or (2) confine it within a channel or channels cut through the area subject to inundation and having a free outlet.

II. *Situation along the lower outcrop of an inclined impermeable stratum, underlying another freely permeable one.* The water falling on the higher ground above sinks through the latter until it reaches the other stratum, by which it is arrested and over which it flows underground until it wells out where that stratum comes out at, or near, the surface. The famous Taráis of India are formed thus. The swamps in the Dehra Dun and the numerous areas of limited extent in the interior of the Himalayas are less striking, but characteristic, instances. Here the cause of swampiness cannot, as in the first case, be removed, but the excess moisture may be got rid of by drainage.

III. *Inadequate outlet for the water entering, or falling over, the area in question owing either—*

(1) *To an insufficient fall,* in which case special drainage works must be resorted to ; or

(2) *To the natural drainage channels being rendered ineffective, either* (a) *by a rough bottom of rock, boulders or stones which impedes the rapidity of their discharge or* (b) *by contractions and irregular bends or a fold of ground running across, whereby the current is obstructed and thrown a long way back.* Here the remedy lies in the removal of all obstructions in the bed of the streams, in the widening of the channels at certain points, and in straightening or rounding off sharp bends. Or

(3) *To an impermeable subsoil.* If this impermeable stratum is neither too thick nor too far below the surface, it may be pierced at a sufficient number of points, especially where it forms depressions, in order to let through the superfluous moisture into the stratum below. If the rock is not very hard and the area to be treated is large enough, special boring machines would be employed with economy. If the thickness to be bored through is too great, or the area is small, a system of drainage cuts cannot be avoided.

ARTICLE 2.

DRAINS.

Drains may be OPEN or COVERED. Open drains are very difficult to maintain, as they are constantly being silted up or choked up with weeds and fallen leaves and twigs. Moreover the best portions of the top soil get washed away into them. But, on the other hand, for forest purposes drains are, as a rule, only required for a few years, that is to say, until the crop to be raised has become established. After that the trees either cease to be sensible to swampiness, or themselves constitute a most effective drain by means of the transpiration through their leaves. Hence, as the covering of drains, especially the larger ones, is very expensive, it should generally be avoided; and in cases of absolute necessity it will often suffice to cover only the smaller drains.

Figures 67-71 represent some simple and cheap, yet effective, methods of covering drains.

In *fascine drains* (Fig. 67) cross-billets of wood *a a*, set up trestle-fashion at regular intervals, support longitudinally laid fascines *b*, upon which, in order to prevent fine soil washing down through them and choking up the drain, clods of turf *c*, grassy surface downwards, are packed. The rest of the drain is filled up with part of the excavated soil.

In *small stone* or *rubble drains* (Fig. 68), from a third to one half the depth of the excavation is filled with clean round stones *a*, which are covered with a layer of turf sods *b* as in fascine drains. Instead of the turf, or immediately below it, a thin layer of smaller stones *c* may be packed.

Fig. 69 represents the usual form of a *box drain*. The sole *a* is paved in order to prevent the stones on the side from sinking, and should be laid with the greatest care and with the largest stones. In building up the sides, a few small stones *b* may be packed under or about the larger ones *c* in order to steady them as well as the covers *d*, which should be placed with their flattest or most convex side downwards so as maintain the cavity as large as possible. If required, small stones, with a covering of sods, may be packed over the box.

Fig. 70 shows two styles of *couple drains*, the triangle formed by the stone slabs being inverted in B. As in box drains, a packing of small stones, topped with turf, may be laid over the drain.

In the interior of the Himalayas, where unsaleable refuse-wood from timber-sawings is available in large quantities, wood may be used instead of stone in constructing box and couple drains, in which case it will always be advisable not to omit the packing of small stones.

When stones or straight small wood are not obtainable cheap enough or in sufficient abundance, drains similar to rubble, box or couple drains may be made with tiles or bricks, whole or broken as the case may require. In ordinary tile drains, semi-cylindrical tiles are placed on a flat sole, as represented in Fig. 71. A simpler, and, for this country, more economical plan would, however, be to burn entire the cylinders moulded for ordinary roofing tiles and to arrange them so that the narrow end of one cylinder fits into the broader opening of that next above it in the drain. Pipe-tile drains will seldom be used on account of the expense.

The best trenching tools for cutting drains are spades, shovels and hoes in soil free from stones, and picks and mattocks in stony soil. The spades should be of sufficient width, according to the diminishing width of the excavation. A shovel much bent at the neck and pointed (Fig. 72), or a spade with the handle considerably bent, are very convenient to finish the bottoms of drains with. Gauges (Fig. 73), showing the depth and width of the drains, are indispensable, as are also instruments for giving the exact fall required. A large level, like a mason's ordinary level, spanning about 10 feet and with the tie bar graduated to read degrees or gradients by means of the plumb-line, is an excellent instrument for the latter purpose.

A system of drains may comprise three inter-subordinated classes of cuts or channels:—

(1) The *collecting* or *primary* drains or cuts, which are intended to collect the excess water from the layer of soil to be drained and pass it on to the next larger drain;

(2) The *receiving* or *secondary* drains or cuts, the object of which is to connect together the primary channels and carry away their accumulated waters; and

(3) The *main* or *outflow* drains, which, when the area to be drained consists of more than one little drainage basin, unite several receiving channels into a single system and conduct the total volume of excess water to the nearest large stream. The main drains are often the natural drainage channels widened and straightened and given the necessary fall.

The collecting or primary drains are necessarily made at the very seat of the swamp, and their number will depend on the area to be drained and the distance apart they are made. If they were cut at right angles to the lines of steepest descent, *i.e.*, along horizontal contours, they would no doubt collect most water, but, on the other hand, the outflow would obviously be impeded; while if they were made to follow lines of steepest descent, they would collect very little, as most of the water would drain away parallel to them through the soil, and flood-waters after heavy rain would rush down and cause erosion. Hence the primary cuts should run somewhat obliquely to horizontal contour lines, so as to collect as much water as possible and yet allow it to run down freely without a tendency to produce erosion. The other two classes of drains should usually follow lines of steepest descent as nearly as practicable (Fig. 74); but when the ground is nearly a dead level, the receiving drains also would best run obliquely to horizontal contours, but in the opposite direction to the primary cuts (Fig. 75).

If the area to be drained is limited and the slope of the ground pronounced, the net-work of drains may be laid out with the eye alone; but when the fall of the ground is not easily appreciable, or the area is large and the surface configuration complicated, a complete series of levels with an instrument should be taken and an accurate map of the ground made showing contour lines at not less than 10 feet vertical intervals. On such a map the system of drains could then be easily laid out (Fig. 74 and 75).

The cross-section of an open drain will depend on the nature of the soil through which it is cut. The ratio of *ab* to *bc* (Fig. 76), which determines the cant of the sides, should never be less than $\frac{1}{4}$ and may go up as as high as 3. Heyer gives the following figures:—

For turf or peat	$\frac{1}{4}$ to $\frac{1}{2}$
„ clay and stiff loams	1
„ sandy loams	$1\frac{1}{2}$
„ sandy soils	2 to 3

The fall to give to drains will also depend on the nature of the soil, and is a direct function of the velocity of current permitted. Heyer's figures for the maximum fall are—

In loose earth	...	...	...	76	per 1000
„ stiff clay	...	...	...	152	„ „
„ sandy soils	...	...	...	305	„ „
„ gravelly soils	...	...	...	609	„ „
„ shingly soils	...	...	...	914	„ „
„ stony soils	...	...	...	1,220	„ „
„ stratified rock	...	...	...	1,840	„ „
„ massive rock	...	...	...	3,050	„ „

For a given velocity of current, the fall F may be determined from the formula—

$$F = \frac{v^2}{(42\ 6375)^2} \times \frac{p}{w},$$

where v = the given velocity of the water at the bottom of the drain, p = the periphery of the section of the drain, and w = the mean width of the section of water at its highest level. As the drains may sometimes fill up to the very top, the value of w should be the same as the mean width of the drain itself.

The interval between two successive collecting drains will depend on their depth, on the permeability of the soil, and on the thickness of the layer of soil to be drained. The following procedure for determining this interval with exactness in any given case is recommended :—

An experimental drain (Fig. 77, *a*), of the proposed section, being cut, several holes (1, 2, 3, 4,.....), of the same depth as the drain, and at equal distances apart, should be successively bored along a line at right angles to the direction of the drain. The drain should then be blocked up until the water in it ceases to rise any more. Both the drain and the holes will be found to have filled up to the same level *mm*. Now open the drain and let it work. The water in the holes will gradually sink, and this the lower, the nearer they are to the drain. In one of them it will ultimately sink down to the depth, down to which it is proposed to drain the soil. The distance of this hole from the drain will be equal to half the distance that must be left between the drains.

The depth of soil to be drained will of course depend on the species to be introduced; but, as a rule, it will not be much more or much less than 3 feet. When the drains are close together, the depth, and, therefore, the total amount of excavation is considerably reduced by banking up the excavated soil between the drains, whereby the level of the ground gets considerably raised.

SECTION II.

FIXATION OF SOILS POSSESSING NO COHESION WHATSOEVER.

Such soils consist of silicious or calcareous sand with practically no substances, such as clay, humus, &c., to bind the loose particles together into a cohering whole. The particles may be large enough never to be drifted about by the wind or they may be so fine that they form perpetually moving waves and hills.

ARTICLE 1.

SANDS UNINFLUENCED BY WINDS.

Instances of such sands we have along nearly all our low coasts and in the loose deposits left by wandering rivers in northern India. They require fixing only in the sense that in most cases a little cohesion would increase their hygroscopicity and give the necessary foothold to trees grown on them. Where a perennial supply of water is close to the surface, as on those low coasts and in many of the river deposits referred to, sowings of woody species may take place at once without any special preliminary preparation, more particularly as numerous grasses and species of Carex with long creeping rhizomes and rooting stems come up spontaneously therein and help to bind together the loose particles to a certain extent. And indeed, even if such plants were absent, they could, if required, be introduced there without any difficulty.

ARTICLE 2.

DRIFTING SANDS.

It is evident that before any forest operations can be attempted in such areas, the drifting about of the sand must once for all be stopped. Experience of such work in India is absolutely *nil.* We can, therefore, do no more here than place before the student certain general ideas, which may be of some practical utility in suggesting special methods when the occasion or necessity for fixing drifting sands presents itself in this country.

We will consider separately the two cases of drifting sands on the sea coast *(coast dunes)* and of those in the interior *(inland dunes).*

We have not, for obvious reasons, included here the case of invasive sands brought down in consequence of the denudation of hill ranges at the upper end of a river basin. In that case the evil can be stopped only by attacking it at its source, *viz.*, by reboising

the hills in question or by putting a stop to their disforestation and conserving the forest growth on them. The consolidation of unstable slopes is treated of in the next Article.

§ 1. *Coast Dunes.*

On many low beaches every high tide leaves behind it quantities of very fine sand, which, drying, is continually drifted inland by the wind and forms moving hills, that may attain a height of more than 200 feet. These hills, as we would naturally expect, have a gentle slope on the sea-face but descend abruptly landwards. Sometimes they are long, continuous, and disposed in regular and parallel lines; at other times they are broken or run zigzag. This depends on the form of the coast line and the direction and constancy or fitfulness of winds. It is to these moving sand-hills that the name of *dunes* has been given. The valleys between the dunes, when these latter are devoid of vegetation, are generally marshy.

On the western coast of France the rate of progression of the dunes towards the interior has been ascertained to be 14 feet a year, and the quantity of sand thrown up annually by the sea to form them about 1,000 cubic feet for every yard of coast-line.

The essence of all the work of fixation is the arresting of the new sand-drifts as soon as they are thrown up by the sea and the protection of the interior hills against the full brunt of the winds blowing from the sea. This double object is secured by the raising of a protective wall with the help of the new deposits brought in by the tides. This wall is nothing more or less than a dune, that is designedly formed, and which, from its position, may be called the LITTORAL DUNE.

The littoral dune is formed by erecting and constantly maintaining, parallel to the coast line and about 100 yards from high-water mark, a continuous line of dead fences or hurdles, against which the drifting sands are arrested. The sand collects on either side of it in the form a long hill, whose backbone is the line of fences itself.

On the west coast of France the following is the procedure:—The fences consist of a line of paling constructed of planks about 6 feet long, 1 inch thick, and about 6 inches wide, and pointed at the lower end. The planks are put into a trench about 1½ feet deep and then driven into the sand, so that when the trench is filled up, only a little more than a length of 3 feet remains above ground. An interval of about one inch should be left between two consecu-

tive planks. The sand is deposited up against the paling sloping gently seawards; but some of it passes through the spaces left between the planks and forms a sort of backing for them, thereby giving them increased stability. As often as the sand reaches the top of the paling and begins to cover it, the planks are pulled up a few feet by means of levers or differential pulleys. In this manner the littoral dune rises gradually higher and higher. All tendency to hurry is avoided in raising the height of the littoral dune, otherwise its height may become too great for its base with the result that its stability would be seriously impaired. To give greater stability to the littoral dune a tight-bound fence about 5 feet high is erected behind the paling. The wattling is at first carried up not more than a yard from the ground; but as the dune rises, it is continued upwards. Since the fence cannot be raised like the paling, a new one has to be erected as soon as the preceding one has been covered by the sand. If, notwithstanding these precautions, the wind is apt to breach the dune, other rows of palings, making a certain angle with the first, are erected on the steep face behind.

When the littoral dune has attained a sufficient height, the formation of a new one may be commenced nearer the sea. In any case the constant maintenance of a littoral dune is an absolute necessity; otherwise every benefit resulting from previous operations must inevitably be lost by the continual drifting in of new sand.

Behind the protection afforded by the littoral dune, the interior dunes are fixed by the planting or sowing of grasses and species of Carex and other plants growing up rapidly and extending themselves by means of rhizomes, suckers or creeping rooting stems. The plants are put down or made to come up in tufts, or, better still, continuous lines, which may consist of two parallel series running at right angles to one another.

Before the seeds are sown or the plants put down, all the steeper slopes on the windward side should be cut down and given a gentle ramp so as to offer as little resisting surface to the wind as possible. The valleys and deeper depressions may also be filled to a less or greater extent by erecting hurdles or fences across them to arrest the sand drifting in their direction.

Until the sowings or transplants are advanced enough to have taken a firm hold of the soil it may be found necessary to protect them against subsequent drifting of the sand. This may done in several ways as follows:—

I. By means of branches containing numerous twigs. These branches are laid end to end over the ground in continuous lines touching one another, and in such a manner that the top of one branch is in contact with or covers the cut extremity of the next. Long poles are then placed across the branches from 4 to 6 feet apart and made fast to the ground by means wooden hooks driven into the latter. It is always advisable to lay the branches in the same direction as the wind, with the cut lower end turned towards the wind, which will then blow over the covering without getting caught under it and disturbing it.

II. By means of twigs spread evenly over the ground and kept in place with a shovelful of sand thrown over each.

III. By means of some long strong wiry grass spread over the ground in the same manner as the twigs.

IV. When there is sufficient moisture, by means of sods of turf arranged as represented in Fig. 78.

Whatever the method of covering employed, it is evident that it should be put down immediately after the sowing and planting has been effected. And it is also evident that so long as no woody growth has established itself, the areas must be rigidly closed to grazing and every kind of trespass, traffic being confined to definite lines, where special precautions, such as the planting of a hedge, erection of fences, &c., should be adopted to keep the soil fixed.

§ 2. *Inland Dunes*

In respect of inland dunes we may have two distinct cases to deal with. In the first place, desert sands may tend to invade areas with naturally consolidated soil; and in the second place, the area itself may consist of continually drifting sands. In the former case, a forward dune must be specially allowed to form, in the same manner as the littoral dune on the sea-coast, along the edge of the invading sand, and as each dune is formed and fixed, a new forward dune should be raised thus attacking and gradually circumscribing the desert. In the second case a line of dunes analogous to the littoral dune should be raised at right angles to the direction of the wind, and under its shelter all the area behind it should be fixed in the same manner as the interior dunes on the sea-coast. If the area is very wide, more than one such artificially formed line of dunes may be required; and, on the other hand, if the drifting process is a very slow and gradual one, the formation of special protective dunes may be quite unnecessary.

SECTION III.

CONSOLIDATION OF UNSTABLE SLOPES.

Very little has as yet been done in India to rewood bare slopes prone to erosion and landslips, and the little that has been attempted has been confined to areas where denudation is a comparatively gradual process. Hence here also we have hardly any local experience to guide us in dealing with cases of a serious character. In the absence of such experience, the following observations, based chiefly on the knowledge gained in the execution of the reboisement works carried on with such marvellous success in the French Alps, may prove useful as suggestions.

ARTICLE 1.

CAUSES OF DENUDATION OF HILL SIDES.

Slopes may become unstable owing to the action of several or all of the following causes :—

(i) *Steep gradients.*

(ii) *Broken surface of the ground and sudden changes of gradient,* causing water to rush down with great velocity at some points, slowly at others, instead of with a smooth even flow everywhere.

(iii) *Schistose or otherwise friable nature of the rocks.* Portions of such rocks are liable to break away by their own weight alone. This tendency is obviously increased by the mechanical pressure of the water that sinks into and fills up the fissures and interstices, and by its solvent action, which is assisted by its constant motion downwards.

(iv) *Free nature of the soil.*

(v) *Clayey nature of the rock or soil,* which, absorbing large quantities of moisture, increases enormously in weight, swells up and becomes soft, and thus either breaks away in masses under the force of gravitation alone or is easily scoured and furrowed and deeply cut into by the surface drainage. Sometimes the clay may absorb so much water that it may be converted into liquid mud. This denuding action of water is still further increased if ferruginous elements are present in the soil, those elements being dissolved out of the soil, which then becomes porous and less resisting.

(vi) *Alternation of rocks of different densities and absorbing water with different degrees of energy.* With changes of weather very unequal expansion or contraction may thus take place throughout the entire mass of the rocks, resulting in the breaking

up and loosening of the entire hill side. The effect is greatest when one of the underlying rocks is clayey and those above let water pass through on to the former; the clay swells and lifts up and breaks the rocks above, or, becoming dissolved and diminishing in bulk, is no longer able to support these rocks, the result being the same in either case.

(vii) *Earthquakes.*

(viii) *Alternation of wet and drought.* The wet causes the soil and rocks to swell up, when, drought ensuing, unequal contraction takes place, cracks are produced and the solidity of the hill side becomes permanently impaired.

(ix) *Alternation of frost and thaw.* Under the action of frost the water in the soil and in the fissures and crevices of the rocks suddenly expands, enlarging all existing cracks and producing new ones. As long as the frost lasts, the frozen water acts as a cement on the loosened fragments and masses; but as soon as the ice has melted, there is nothing left to hold them together.

(x) *Pelting or abundant rain.* The impact of the innumerable drops following one another in quick succession obviously disturbs the surface of the hill side; while the fallen rain, increasing its mass and density by means of the suspended and dissolved matters it takes up and gathering velocity and momentum as it rushes down the hill side and tears up gravel, stones and larger fragments, carries almost everything away before it.

(xi) *Wind, especially when it drives rain or hail.*

(xii) *Lying snow*—its weight, and, when it has frozen and formed a single solid mass with the surface of the hillside, its breaking away in avalanches and its constant slow glacier-like motion downwards.

(xiii) *Absence of forest growth.* A covering of trees protects a hill side by attenuating or completely nullifying the destructive action of all the preceding causes except earthquakes. The dense, strong network of roots, anchored fast in the solid rock below, holds together, even on very steep slopes, loose, crumbling rocks or soil, which would otherwise slip or be washed down below. When rain falls, the crowns, and, to a smaller extent, the trunks of the trees, sustain the first shock of the drops. A portion of the water descends on the soil below in spray, another trickles down the trunks of the trees, a third drips slowly, but with very much less velocity and, therefore, momentum than the original rain-drops, from the leaves and branches, while a fourth is

evaporated back into the atmosphere, and a fifth adheres by the force of attraction to the trees or is absorbed by them superficially. Thus of these five portions, only three reach the ground, comprising, according to Ebermayer, only about 75 per cent. of the total precipitation; and then it must be remembered that a, by no means, inconsiderable portion of this quantity goes on dripping from the tree-tops for some time after the shower itself has ceased. Of this 75 per cent that ultimately reaches the ground, one portion descends at once by way of the roots into, and is held by, the entire depth of soil penetrated by those roots, a second is absorbed by the covering of dead leaves and low vegetation (vegetable mould absorbs nearly twice its weight of water, moss up to six times) ,while a third, if any remains, ultimately filters down slowly through this loose impeding mass into the drainage channels, taking as many hours to reach the valley below as the shower took minutes to fall. Thus the water never rushes down the hill side, and can do no damage to the soil, which is moreover protected by its dead and living vegetable covering and the close network of roots; the streams and, at any other time, dry gullies and ravines rarely become swollen torrents, but more or less perennial rills gush down the mountain side and the larger watercourses never run dry. The water that sinks into the ground is partly absorbed by the roots and finds its way through the leaves back into the atmosphere which it keeps moist, is partly retained by them by the force of capillarity and their own suction power, while a third part filters downwards and re-appears below to feed or form springs. At no time have the upper layers of the soil to bear more than a fraction of the weight of water within them and the almost imperceptible underground flow is never a danger to its stability. If snow falls, the trees catch and retain a large portion of it, and what reaches the ground is held in place, until it melts, by the trunks of the trees and the low vegetation below, whereby heavy drifts and, as long as the trees stand, avalanches and the slow downward glacier-like motion of the snow are prevented. When spring comes, the snow thaws gradually, first on the tree tops, then on the ground below, latest of all in the deep, tree-sheltered ravines. Like the rain water, part of the melted snow sinks into the soil, a part is absorbed by the dead vegetable covering over it, through which covering the remaining portion trickles down slowly to the drainage channels. The crowns of the trees, as long as they are in leaf, shelter the soil and retard evaporation from it, and if the crowns become leafless the covering of dead

leaves and grass and other low vegetation and the spongy network of roots are still there to prevent it from losing its moisture except very gradually. Under the crowns of the trees and the ground-covering of vegetable detritus the soil can seldom become baked and cracked by a torrid sun and is, even at the surface, to a great extent protected from frost. Lastly, the mass of trunks, branches and leaves breaks the force of wind and hail.

ARTICLE 2.

PROTECTIVE WORKS.

Protective works undertaken to render treeless, unstable slopes fit to be sown or planted up with forest species need only be limited to (A) holding together crumbling rock or soil, (B) checking the excessive velocity of the flood waters at certain points in the streams and gullies, and (C) providing a free outlet for rain and snow water, so that no quantity of it may sink into the ground sufficient to soak and convert into liquid mud, and to saturate, break up and undermine, the rock below.

A. To accomplish the first of these three objects, the dangerous portions of the hill side, especially the gullies and ravines should be cut into terraces, the width of which will be in inverse proportion to the steepness of the ruling gradients. The terraces should be given a decided slope outwards and their faces should be protected by revetment walls. As these walls have only a temporary utility, that is to say, are required to hold the soil together only until the covering of trees with their dense network of binding roots has been established, dry masonry will be the rule, pakka the exception, and then too only confined to the most dangerous points and to cases of absolute necessity. The revetment masonry between two terraces will often have to be continued for a few feet both upwards and downwards along their floor (Fig. 79, *a* and *b*) in order to protect it against erosion. Indeed it may sometimes be necessary to continue the pavement across the entire width of the terraces, in which case long blocks of wood may be laid between the masonry to tie it together (Fig. 79 *c*). But instead of paving the entire floor it will suffice to put down paving stones in lines forming a sort of check pattern (Fig. 79 *d*). In forming this pattern blocks of wood may be substituted

for the rows of paving stones, in which case the pattern will resemble Fig. 79 *c* without the paving stones. In dangerous places numerous long headers ought to be used in the revetment walls, better still blocks of wood as shown in Fig. 80.

B. To accomplish the second object the channels of the water-courses must be regulated. Contractions have to be widened, sharp bends gently rounded off, the angle at which one watercourse meets another altered, and so on, all these various works having for their common object to secure as much as possible an even flow. But the most important point of all is the graduation of the beds of the channels in the direction of their length; all hollows must be filled up, obstructions removed, and the fall so regulated that it gradually diminishes downwards in order to counteract the constant acceleration of velocity of the current due to the force of gravitation.

Owing to the usually steep gradients where such work has to be done, the main end can be secured only by forming the beds into a succession of terraces. The water falls from terrace to terrace, erosion being prevented by means of masonry or other revetments, and flows smoothly down each terrace.

When the fall permits of it, the simplest plan to follow in forming the terraces is to throw dams across the channels at well judged intervals, and of the right height, and strong and tight enough not to be breached. Stones, gravel, silt &c., brought down with the water, will then gradually collect behind each dam until the bed of the stream rises up on a level with it, thus ultimately forming an even terrace having a gentle slope outwards. The more rapid the fall is, the nearer together must the dams be constructed. The material of the dam will depend on the maximum volume and velocity of the water coming down at any time. To use pakka solid masonry in all the dams would, by reason of the expense, be impracticable, and hence only the larger and stronger among them should be so built. In many cases a dry stone wall, of sufficient width, thrown across will suffice, the silt collecting behind it soon making it more or less tight. Another excellent style of dam is represented in Fig. 83, which explains itself.

All dams constructed of dead material have against them this drawback that they must be at once made of the required height, and are besides very expensive. In the French Alps a tight live fence of some strongly-rooted, easily slipped, and quick growing shrub has proved an effective substitute for masonry. The fence

is put up low, but gradually grows up, and it never, like other descriptions of dams, allows the water to rush over it and fall clear of it in a single mass, which tears the ground away where it falls. A further plan, often adopted with great success, is to erect two parallel strong, tight-bound live or dead fences a few feet apart from one another and to fill the interval with boulders and rubble.

When the fall is very rapid, the terraces must be completed at once without delay and may have to be made so narrow as to assume the appearance of a flight of steps.

If the material of the mountain side is very loose, the sides of the ravines may have to be wholly or partially lined with dry stone masonry and even buttressed up by cross-walls in continuation of the line of the edge of each terrace.

C. The third system of measures is intended to attack the evil at its very source. At the head of each drainage basin, all over the mountain-side, a well-devised system of drains is cut, which collect rain and snow water and give it immediate egress to the larger natural drainage channels, without allowing any considerable proportion of it to sink into the mountain-side, thereby preventing its soaking and softening the latter and destroying its stability.

We have seen that in the drainage of swamps no regard at all is paid to the quantity of moisture in the layer of the soil below that which is to be rid of its superfluous moisture. Here it is essential that the lower layers shall receive as little as possible of the atmospheric precipitation, that this precipitation shall affect as thin a layer as possible of the earth's surface, and that the *entire* stratum containing an excess of moisture shall be drained. Hence the principles to follow in the present case will differ from those observed in designing, cutting and constructing the drains in the other case mainly in the following respects:—

(i) None of the drains should be covered, so that they may act as quickly and with as little delay as possible, and allow as little as possible of the atmospheric precipitation to sink into the earth.

(ii) The receiving and outflow drains should be given a more rapid fall, and must therefore be more carefully protected against erosion.

(iii) The collecting drains should be as deep as the greatest depth down to which superfluous moisture penetrates.

SECTION IV.

IRRIGATION WORKS.

The great Changa Manga plantation owes its remarkable success to the excellent system of irrigation adopted there ; and indeed we may go so far as to say that it is owing to this irrigation that the plantation has at all been possible. Almost everywhere outside the Himalayas drought is one of the greatest, if not the greatest, obstacle to the stocking of bare wastes ; to it must be traced most of our numerous failures even where the annual rainfall exceeds 40 inches, and to it is due the now proverbial charge made against us of inability to restore, within a reasonable time, the enormous areas of ruined forests that past improvidence has handed down to us. Such being the case, wherever the Canal Department has water running to waste, or natural facilities exist for the construction of a cheap but effective system of irrigation works and the requirements of the population in respect of forest produce are insufficiently met, there irrigation should be resorted to without hesitation, as the certainty and rapidity of success will repay, over and over again the special outlay entailed. Even well irrigation will be practicable and remunerative near large markets where the water level up to the early part of March is not more than 10 to 15 feet from the surface and no rock has to be bored through.

For canal irrigation no better treatise on the construction of the necessary works specially adapted to the conditions of this country exists than the Rurki Manual, to which therefore the student is referred.

The following paragraph adapted from Ribbentrop's "Hints on Arboriculture in the Punjab," describing the system followed in Changa Manga, will be found interesting as well as instructive :—

"There are three descriptions of irrigation cuts, (i) the rajbahas or main feeders, (ii) the secondary feeders, and (iii) the trenches or distributing channels. The rajbahas receive the water direct from the canal by means of a water head or *Mogha*, the secondary feeders convey the water from the rajbahas to the different points of the area to be irrigated and the trenches bring the water up to the plants. The width and depth of the first two classes of channels of course depends on the area which they are required to serve. The width of the section of a rajbaha may be from 12 to 14 feet at the top. The exact dimensions to give to the secondary

feeders, of which there is one for each compartment, are more difficult to calculate and depend not only on the area of the compartment in question, but on the fall attainable. The trenches are only 1' × 1'. In loam the large channels are given sloping sides of about 45°. In sandy loam or sand the cant is stronger, increasing in fact with the looseness of the soil. It is of the utmost importance to give an uniform fall to the feed channels, otherwise silting up of the beds and the destruction of embankments must ensue. The fall we adopt depends chiefly on the fall in the canal and the height of the weirs from which we receive the water. We have everywhere tried to obtain the highest fall possible up to a maximum of from 1 to 1½ feet per 1000. Care is to be taken that the excavated earth from the feed channels is thrown up equally on both banks. The silt and vegetation that collects in the channels is cleared each time they are to be used."

CHAPTER IV.

DIRECT SOWING.

In direct sowing success depends on the correct appreciation and due observance of the following six conditions:—

I. Proper selection of the species to sow;

II, Employment of good seed (this has been fully dealt with in pages 143-149);

III. The most favourable season for sowing;

IV. The quickest, cheapest and most effective mode of preparing and sowing the ground;

V. The right quantity of seed to sow; and

VI. Adequate care of the sowings until they are established.

SECTION I.

Selection of the species to sow.

On the proper selection of the species to sow more than on any other consideration depends the success of direct sowings. In nurseries seeds are sown in highly prepared soil within a small manageable area, and are carefully protected during germination; while, after germination has taken place, the young plants receive almost individual attention and are carefully guarded against all harm. In direct sowings, on the other hand, the work is spread over such immense areas, that anything like minute supervision and tending is quite out of the question; the seeds, and after them the seedlings, receive a minimum of attention, and the latter are, from their most tender age, left more or less completely to take care of themselves. Whence the great importance of a correct choice of the species to be sown.

This choice is, at the very outset, necessarily limited to those species which can best fulfil the object in view. That object may be very various. It may be the production of certain special or general classes of timber, fruit, &c. in quantities proportionate to the probable demand, or the raising of a preliminary or nurse crop, or the protection of hill-sides or the plains country below, or a

favourable modification of the climate, &c. Then from among these species only such can be selected as are likely to succeed under the given conditions of soil, climate and other surroundings. Those whose seeds germinate with difficulty (*i. e.* take time or require specially favourable conditions), or go bad easily, or are sought after by numerous and destructive enemies, must in any case be avoided.

The selection of the species to sow thus requires the most careful and judicious consideration based on ripe experience and a thorough grasp and appreciation of the prevailing conditions under which the stocking operations are to be undertaken. The simplest case occurs when the sowings are to be effected on land that is, or has only recently been, under a crop composed, amongst others, of one or more valuable and suitable spontaneous species. Then the choice admits of little or no hesitation, and each such species must be sown in the soil and locality for which it is best suited.

SECTION II.

Season for sowing.

In the temperate and alpine regions of India, the Himalayas, if we except the case of such seeds as ripen during the summer rains and cannot be kept and must therefore be put into the ground at once, autumn sowing will, as a rule, yield the best results. Where snow lies, the seeds will remain protected under it, and as soon as the latter has melted, being already thoroughly soaked, they will germinate during the first warm days of spring; and where no snow falls, or melts soon after it falls, the seeds will still be completely protected under the soil throughout the cold of winter, particularly against mouldiness, fermentation and insects, and, as in the preceding case, they will germinate in early spring. Thus, in either case, the seedlings will have before them the remainder of spring, the whole of summer and part of autumn in which to develop and strengthen themselves against the next ensuing season of frosts. Sometimes, however, in order to avoid spring frosts or the sudden occurrence of cold and raw or hot and dry weather in May-June, it may be advisable to sow in the rains.

Elsewhere in India the best season for sowing is generally the commencement of the summer rains, because, in the first place save during that season, there is never any certainty of finding sufficient moisture in the soil, and, in the second place, seedlings

that come up later in the rains or at any other time of the year would have little or no chance of surviving the bright strong sun of September-October, the cold nights of October-February, or the following hot weather, as the case may be. Nevertheless when the area to be operated upon is large, or when sufficient labour is not available at the exact moment, a part of the sowing must necessarily be performed before the rains. No lamentable results need, however, follow this violation of the general rule, for, protected inside the soil, the seeds would suffer little or no harm from the dry heat prevailing at that time of the year; and actually the seeds of many valuable species, such as sissu, the *Terminalias*, &c., sustain no injury whatsoever if sown several weeks or even months before the setting in of the summer rains, provided of course no continuous wet weather intervenes. Indeed in the case of teak, the germination of the seeds of that species is, on most occasions, so protracted, that it is advisable to sow immediately after the close of the summer rains or as soon as the cold weather has begun: continued contact with the wet soil, followed by the drought of the hot season will exercise a forcing effect on the seeds. The seeds of species, which, like sal and some others, ripen at the beginning of the summer rains and cannot be preserved, obviously give no room for choice or delay, and must be sown as soon as they are ripe.

SECTION III.

Preparation of the soil and sowing in general.

If not already so, the soil should be brought into a favourable condition for the sowing and germination of the seeds and the subsequent prosperous growth of the young plants. It ought to be loose enough and sufficiently free of living roots of extraneous plants, in order at first to give the seeds a good clean warm bed easily penetrated by air, and then to enable the seedlings to strike their roots deep and readily, by saving them from invasion by other plants, and by allowing fertilising atmospheric influences to enter itself freely and maintaining within itself an equable and genial temperature. The stiffer, richer, moister, or more abundantly traversed by roots and rhizomes the soil is, the deeper and more completely must it be worked up and cleaned, weeds and brushwood covering it being previously cleared, if necessary. But a naturally free soil should not generally be turned up deeper than the seeds are to lie, so as to minimise the evaporation from it and to prevent water of atmos-

pheric precipitation from sinking down too rapidly and deep. If there is a thick covering of undecomposed or only partially decomposed vegetable debris on the surface, this should be removed from the points where the seed is to be sown, or it should at any rate, if not too abundant, be thoroughly worked into the soil below. If the soil is sour, it should be turned up deep and freely aërated. Where insects are abundant, the more open and sunny and suitable for their breeding the locality is, the lighter must the soil be worked.

The best time for preparing the soil for summer sowing, where snow does not lie or there are no winter rains, is the beginning of the dry season immediately following the summer rains: the soil is then still moist and yielding and hence easily worked up, and the long exposure to the atmosphere before the seed is sown, aërates and comminutes the portions turned up and helps to decompose the incompletely reduced organic remains it contains. Otherwise the work must be done in early spring. For autumn sowings, which are of course confined mainly to the Himalayan region, the soil must be prepared in October soon after the S. W. monsoon rains are over.

As regards the sowing of the seeds, it should be so effected that they are exposed to as few risks as possible during the whole time that they have not completely germinated: these risks are (i) being blown away by the wind, (ii) being washed away by rain, (iii) being devoured by animals, (iv) becoming rotten from excessive or stagnant moisture, (v) fermentation, (vi) being killed, or at least badly injured, especially when the process of germination has already begun, by heat, frost or drought.

One of the most effective precautions to take against these various risks is to bury the seeds to the right depth in a clean, sufficiently loosened soil. The maximum depth of sowing is rigorously fixed by the length of stem between the root collum of the seedlings and the first pair or group of leaves, which, when germination is complete, should stand clear of the soil. Between this maximum depth and the mere scattering of the seeds over the surface of the ground, the various depths of sowing will be determined by the imminence and potency of the risks enumerated above and by the following additional considerations:—the size of the seeds, the time they take to sprout, their exacting nature as regards the conditions necessary for germination, the ease with which, in epigeal germination, the cotyledons burst forth and leave the seed cap, the delicate or hardy constitution of the region of

the root collum in the young seeedling, and the stiffness and hygroscopicity of the soil. Thus, the stiffer the soil is, the shallower ought to be the sowing in order to secure sufficient aëration for the seeds and the newly developing radicle; the greater the likelihood of frequent breaks of dry weather occurring during the process of germination, the deeper must the seeds be buried; and so on.

SECTION IV.

Different methods of sowing.

The ground may be sown without any preliminary cultivation, or it may be subjected to a certain amount of previous tilth. In the former case the seed may be broadcast more or less uniformly over the entire area to be stocked or it may be dropped into small holes or cuts *(notches)* made in the ground. In the other case, the entire area may be cultivated and sown, or the operation may be partial and restricted to certain definite portions. When the sowing is only partial, the cultivated portions may form more or less continuous parallel lines or consist of only detached spots of very limited extent. Then again, the continuous lines may be on the same level as the rest of the ground *(strips)*, or hollowed out in the form of *trenches* or *furrows*, or raised into *ridges*, or combine the form of any two or all three of these methods; while the detached cultivated spots, according to their size and form, may be *patches* or *plots*, *pits*, *hollows* or *holes*, *mounds*, or combinations of patches, plots, pits or hollows, and mounds. These various methods may be exhibited synoptically thus:—

- **Direct Sowing**
  - Without tilth
    - Complete 1
    - Partial
      - By dibbling 2
      - In notches 3
  - With tilth
    - Complete 4
    - Partial
      - In continuous lines
        - Strips 5
        - Trenches or furrows ... 6
        - Ridges 7
        - Combinations of 6 and 7 ... 8
      - In lines of detached spots
        - Patches 9
        - Plots 10
        - Pits or hollows 11
        - Holes 12
        - Mounds 13
        - Combinations 9, 10, 11 & 13 ... 14

ARTICLE 1.

BROADCAST SOWING WITHOUT TILTH.

As the name of the system implies, the seeds are sown broadcast without any previous preparation of the soil. In order that the system may succeed, all or the majority of the following conditions must co-exist:—

(1) The soil must be free from all rank growth of weeds or low bushy shrubs.

(2) It must be naturally more or less free.

(3) It must ordinarily retain moisture at or near the surface during a considerable part of the year, since, owing to the unloosened soil, the tap-root of the yearlings must generally be short.

(3) The seeds used must be possessed of great vitality, or, at least, germinate readily.

(5) Seed must be extremely abundant and cheap, since, owing to their lying completely unprotected on the surface of the ground, many and even the majority of them necessarily fail to germinate, and on this account the sowing must be very profuse.

(6) No climatic extremes must prevail.

(7) The young seedlings must be extremely vigorous and hardy and able to develop a long, strong tap-root.

(8) The ground must not be too sloping, particularly if heavy showers occur.

In short this method may be successfully adopted only where the conditions for germination and for the subsequent struggle for existence are unusually favourable. It may be employed with good results to introduce or increase, more rapidly than natural regeneration would do, the proportion of a tenacious species in an already existing forest, especially if that species is more shade-enduring than its companions. Where frosts and drought do not prevail, or are mild enough not to be dangerous, a hardy and quick growing species, like *Pinus longifolia*, teak, &c., for instance, may be sown on more or less open land that is not too hard or too thickly overgrown with tall and strong weeds

The great point in favour of this method is its cheapness, and the rapidity and ease with which the sowing is executed, requiring next to no supervision and no skilled or specially trained labour. Where the prevailing conditions are favourable for its employment and time is of little or no consequence, it should be preferred without any hesitation to every other.

ARTICLE 2.

DIBBLING.

DESCRIPTION OF THE METHOD.—In this method a hole is made with a dibber (Figs. 82, 83 and 84) and a seed or two dropped in and covered to the right depth. The holes should be made in a regular manner along straight parallel equidistant lines, in order both to ensure uniformity of sowing and to facililate the actual carrying out of the work and supervision, and control afterwards. The holes may be made either singly at equal distances apart or in uniform groups of two or more together with equal intervals between two consecutive groups. Whatever the arrangement, there ought generally to be from about six to nine holes per square yard. After the seed has been dropped in, the hole should be filled up by pressure with the foot or fingers, or by scraping soil into it from the edges.

VALUE AND EMPLOYMENT OF THE METHOD.—This system is evidently an improvement on the preceding. In the first place, it requires less seed, and, in the second place, the mode of sowing the seeds protects them to a very great extent against harmful external influences and gives them some sort of a bed, whereby the development of the taproot is favoured and the vigour and tenacity of the seedlings remarkably increased. Hence it will succeed not only wherever the other has any chance of success, but also in places in which the latter would completely fail. Its employment requires a more or less loose and moist soil, free from powerful and invasive weeds, and a species that naturally develops a strong taproot. It is well adapted for filling up small blanks in a forest and for introducing or extending a given species under the cover of a more or less open standing crop of old trees.

ARTICLE 3.

NOTCH SOWING.

DESCRIPTION OF THE METHOD.—In this method an oblique notch is made in the soil with a spade or hoe, one or more seeds are dropped in, and the notch closed over them with the pressure of the foot. The notches should of course be arranged in lines, but as several seeds can be sown in a single notch, there is never any necessity to make them in groups. The notches may consist of a single cut each or they may have the form of a T. In cross-cut sowing, as this latter system is called, the best place for the seed is generally the junction of the two notches, but more seeds

may be dropped in at other points also. The spade used should be a straight one, with a thick blade gradually narrowing towards the edge (Fig. 85.) The planter's hoe (Fig. 22) can be used in drier, harder soil than the spades.

VALUE AND EMPLOYMENT OF THE METHOD.—The notch system in general, like the preceding, necessarily implies the absence of strong or invasive weeds, a naturally loose, deep, good soil, the development of a powerful tap-root, and, if the species used is delicate, either a mild, moist climate or the shelter of canopied forest overhead. As compared with mere dibbling, the present method enjoys this advantage that the long wound made in the soil is more favourable for root-development than the very restricted hole made by the dibber; and for this reason, and also because more than one seed is sown in each notch, the number of notches, area for area, would be considerably less than the number of holes. But, on the other hand, the notch system requires the soil to be in a softer condition at the the time of the sowing.

ARTICLE 4.

COMPLETE SOWING WITH TILTH.

In this method, after a less or more complete preparation of the soil, the entire area is uniformly and more or less thickly sown.

§ 1. *Preparation of the soil.*

In preparing the soil three different procedures may be followed, according to its actual condition.

I. If the soil is naturally free and the growth of weeds is very slight, a simple raking or harrowing or a merely superficial hoeing will suffice. Such a soil we may, for instance, have where a well-conserved forest has just been felled or opened out, or where a field has been recently abandoned. If the ground is open enough and free of stones and large roots near the surface, harrows (Figs. 20 and 21) may be used. Where there are too many stems standing to permit of the manèuvring of a harrow, rakes must be substituted. Owing to the work required of them, these rakes should be strong and heavy, and made entirely of iron and steel: a useful model of one, that can be used like a hoe as well, is the drag (Fig. 41). If woody roots are numerous, the most effective tool to employ is the hoe. It may be of any one of the patterns represented in Figs. 16, 17, 22, 40, 86 and 87, the last but two of which is an extremely convenient implement, as it combines a hoe and rake in one and the same tool.

II. In the next place, the soil may, as in many of our Himalayan forests, be covered with a mass of more or less undecomposed vegetable disjecta, so thick that only an insignificant portion, if any, of the roots of yearlings can reach the true soil below, and at the same time close and spongy enough to retain sufficient moisture during the season of vegetation to prevent those roots from extending themselves beyond it in search of water. Yearlings so conditioned remain ill-nourished, and when, on wet weather ceasing, the spongy mass dries up, their roots dry up with it and they die or, at least, get permanently weakened.

In such places the obnoxious dead vegetable covering should be so far removed, or, if it is not too thick, so worked up into the soil below, as to give seedlings just sprouting a chance of sending down their roots at once into the true mineral soil. The drag (Fig. 41), hoe axes Figs. 16 and 17, pickfork (Fig. 40) and the hoes represented in (Figs. 86 and 87), are excellent tools for the purpose. The hoes must be light and rather long and narrow in the blade. If the ground is level enough to preclude any fear of slipping or erosion, cattle may be driven over the area just before the sowing operations: their weight, combined with their sharp cloven hoofs, will suffice to crush and comminute the coarse debris and force them into the soil. If domestic swine are available in sufficient numbers, they would be better than all the cattle and implements in the world, as their feet are not only sharper, but they are more active and with their snouts work up the surface soil thoroughly, at the same time destroying insect grubs and rats and the roots of weeds.

III. Thirdly and lastly, the soil may be so stiff or so covered with strong brushwood and weeds that neither of the two procedures already described would answer. Here, first of all, it is necessary to clear away all the obnoxious low growth. This may be done with bill-hooks, light axes or hoe-axes for the larger woody plants, and sickles or, still better, scythes (Fig. 88) for those that are more slender or herbaceous. Next, the soil must be worked up.

If the area is clear of trees or large boulders and roots, it should be ploughed up. The ploughs used must necessarily be very powerful and fitted with a coulter (Fig 18, *c*) to cut through moderately thick roots. If the ground is not suited for the plough, then there is no help for it but to resort to the very much slower and more expensive employment of picks (Fig. 13) or hoes, assisted wherever necessary

with the grubbing axe (Figs. 14 and 15). The hoe should be heavy and strong, with a blade narrow enough to give it penetrating power. The various patterns represented in Figs. 22, 16, 17 and 87 are excellent ones according to circumstances. But it is obvious that the use of hoes and picks, by reason of the enormous expenditure it entails, cannot be generalised and must be confined to very exceptional cases and to the preparation of areas of very limited extent.

It is evident that whether the plough or pick or hoe is used, the depth to which the soil is broken up will be in direct proportion to its stiffness, to the quantity of invasive roots it contains, and to its strong nature.

§2. *Sowing the seed.*

The sowing may be effected broadcast with the hand, or by means of drills or other special machines.

When the plough is used in preparing the ground, the ordinary sowing tube of the Indian cultivator (Fig. 89), attached to and dragged behind the plough in the furrow just made, would be advantageously used. *f* is a wooden funnel, into which, with his right hand, the sower keeps dropping the seed; *t* is a thin hollow bamboo, about 3 feet long, the bore of which must obviously be wide enough to allow the largest seeds sown to fall through freely. With his left hand the sower guides the tube and holds it constantly vertical. The thickness of the sowing is regulated entirely by the sower; the thicker the sowing is to be, the more seed he has to let slip through his fingers. If the seeds are small, and are on that account likely to fall too thick, they should be mixed with fine dry earth or, better still, with vegetable mould, farmyard manure or surkhi ash. With this tube seeds of any size can of course be sown. The great advantage of using this and the implement next to be described is that the sowing is effected in continuous parallel lines, thereby facilitating very considerably after-supervision.

Another very useful but simple and easily made and maintained contrivance, which may be used in whatever way the ground has been prepared and at any time after the plough has been used, is the *perambulator drill* (Fig. 90). The seed is put into the hopper *h*, at the bottom of which rotates horizontally a cylinder *c*, grooved longitudinally along its circumference and connected by means of an endless driving band with the wheel *w*. *st* is a flat strip of iron sliding backwards and forwards, by means of the

adjusting screw *sc*, across the opening at the bottom of the hopper and thereby regulating the feed of the seeds from the latter. As the implement is pushed along, the wheel *w* rotates, setting in motion the cylinder *c*, the successive grooves of which catch and take on the seeds that have passed down from the hopper and, with the revolution of the cylinder, drop them through the tube *t* over the point of the small share *sh*, and thence into the furrow made by the share. The advantage which this machine possesses over the simple sowing tube is that the quantity of seed sown can be exactly regulated without any trouble or fatigue by the merest tyro and the share can be adjusted so as to make a furrow of the depth required. But the sowing of large or winged seeds, like those of sal, *Terminalia tomentosa, &c.*, is entirely precluded.

Sowing broadcast requires a certain amount of skill and much more careful management than drill sowing, and in any case it does not distribute the seeds so uniformly. Moreover it can seldom be performed except in calm weather, particularly when the seeds are small or light or flat or winged. A light drizzling rain makes the work easier.

Whether we sow broadcast or in drills, great care must be given to secure an equal distribution of the seeds. To this end the area to be sown should be divided, by flags ranged in parallel lines, into a number of small temporary compartments of equal extent, and the seeds into the same number of equal lots. Although the sowing in each compartment taken singly may not be quite uniform, nevertheless the distribution of the seeds over the whole area will be sufficiently equal for all practical purposes.

If there are several species of seeds to be sown together, they may be thoroughly mixed beforehand in the proper proportions; but, if sowing drills are used, it is much better to sow each kind separately in alternate lines or according to any other arrangement suiting the proportion of each to be sown, as by no other means is it possible afterwards to ascertain exactly and with ease the relative success of the several kinds sown, and hence whether the required proportion of each species exists on the ground.

Whatever the mode of sowing, the seeds must be sown thickly: however good the quality of the seeds may be, a large percentage must fail to germinate, and, owing to the wholesale, and therefore necessarily rough and ready, manner in which the ground has been prepared, a very much larger proportion

of the seedlings must die. At least 10 seeds must be sown per square yard.

§ 3. *Covering the seed.*

In sowing with the tube, a weighted brush of twigs may be attached to and trailed behind the tube, and thus cover the seeds immediately they have been sown. The going to and fro of the plough cattle and the workmen presses in the seeds still further and the soil over them. When large seeds have been sown, an ordinary roller clod-crusher may be passed over after the sowing has been effected.

With the perambulator drill, as large seeds are never sown with it, the workman walking behind it treads down the soil sufficiently in most cases. If further measures are necessary, a twig may be tied broom-fashion and attached just behind the dropping tube (Fig. 90, *br*), or bush-harrows (Fig. 91) or roller clod-crushers may be drawn over the area.

When seed is broadcast, it may be raked over or pressed into the ground with rollers according to the depth of covering required.

In whatever manner the seeds are covered, it must not be forgotten, that besides burying them down to the right depth, they must everywhere be brought into sufficiently close contact with the soil in order to be protected against unfavourable accidents of the weather. Hence the means to be employed in any case will depend partly on the way the ground has been prepared and sown, partly on the size and nature of the seeds and character of the resulting seedlings.

§ 4. *Value and employment of the method.*

It will have been seen that this method of sowing requires a very large expenditure of labour, supervision and seed, and, therefore, of money also.

Again, however thickly we may sow, unless every prevailing condition is uniformly favourable (a very rare contingency), the seedlings come up unequally; in some places there are none at all, in others they are few and far between, while elsewhere they may stand too close together, the result being that the sowings generally grow up badly, repairs and other improvement operations are very difficult to execute and control, and often it becomes impossible, or next to impossible, to distinguish failure from success.

But, on the other hand, when the seedlings do come up more or less uniformly, they meet their crowns and close over the ground earlier than in any other method, thus not only arresting at once the deterioration of the soil from exposure, but also affording each other mutual protection and engaging with each other in a struggle for existence that forces them up in height, prunes their boles naturally, and produces clean, straight, sound timber.

But, all points considered, the only four cases in which the adoption of the method may be justified are—

(i) When the soil is apt to be overrun with a dense mass of tenacious invasive weeds.

(ii) When the area to be sown has just been under field crops, and is, therefore, already in a very high, if not complete, state of preparation for the sowing of forest seeds.

(iii) When one or two field crops can be taken off the ground, in which case the cost of preparing the soil would be, to a great extent, or entirely or even more than, recouped by the sale of the field crops, while the forest seedlings themselves could be raised simultaneously with those crops and be protected by them during the most tender stage of their existence.

(iv) When small areas of a hundred square yards or so are to be sown up.

ARTICLE 5.

Strip sowing.

In this, as in all the following methods, only a part of the entire area is cultivated and sown. Here the ground is cultivated in narrow, more or less parallel, equidistant and continuous strips, the uncultivated intervals being much wider than the strips.

§ 1. *Length of the strips.*

It has been said that the strips are more or less continuous. On level ground, their length may of course be indefinite and limited simply by the extent of the area across which they run. But on slopes and on uneven ground it is evident that they must be broken up into short lengths, on the latter in following the configuration of the ground, and on the former in order to leave a sufficient number of intact intervals over which the main rush of surface drainage may pass without producing erosion. The more broken the ground, the steeper the slopes, and the

heavier the rainfall on the higher ground above, the shorter must be the strips and the longer the uncultivated gaps between.

§ 2. *Direction of the strips.*

The vegetation standing on the uncultivated intervals will obviously afford considerable protection to the young plants in the strips against frost, excessive insolation, winds and erosion. We will first consider what direction it would be safest to follow, supposing that only some one alone of these four dangers was imminent, and then discuss what compromises should be made when any two or more of them acted together.

Frosts. Where continuous frosts prevail, it is evident that that direction would be the most to be recommended which gave the plants the fullest benefit of the sun's influence. During the season of frosts, the sun is low down in the south. Strips running N. E. and S. W. would be warmed by it throughout the afternoon (when it is most powerful) until it set, and would therefore never cool down to such an extent as strips running in any other direction, particularly that joining the eastern and western points of the compass. Where only night-frosts prevail, the morning sun must in any case be avoided, and here again a north-easterly direction would be the best: while it would protect the young plants from the morning sun, it would also retard radiation from the strips and thus mitigate, if it did not altogether prevent, frost.

Excessive Insolation. In the hot weather, when alone this danger exists, the sun rises for every place in India more or less due east and sets more or less due west. Hence in strips running east and west the seedlings would receive next to no shelter from the vegetation standing on the adjoining uncultivated intervals, that is to say, would be practically exposed to the sun's rays during the whole time it remained above the horizon. On the other hand, the young plants would receive most shelter, if the direction of the strips were due north and south; they would then receive the sun's rays only from some hour before noon to the same hour after it had passed its zenith, the length of time depending on the height and density of the vegetation referred to and on the width of the strips.

Dangerous Winds. It is obvious that the strips should run as much as possible at right angles to the direction of such

winds. Saving local deflections due to the configuration of the ground everywhere, and the sinuosities of the coast line near the sea, the direction of violent winds in India is either north-west or north-east or south-west. When not bringing rain, the current that blows north-east also becomes a hot wind at a certain distance from the coast. In the Himalayas the *dhadu* or chilly wind that blows down from the snows, naturally sweeps down the longer valleys, which of course all open out to the south. The direction of the strips with reference to dangerous winds is thus a very variable one, depending on the position of the place with respect to the sea and to the configuration of the land in the neighbourhood.

EROSION. It is obvious that if the soil on decidedly inclined ground is loosened in any direction but that following horizontal contours, rain or snow water, rushing downwards, would scour and wash away the loosened soil in the strips, together with the seeds or young plants that the latter may contain, and thus also endanger the stability of the slopes.

GENERALISATION. In aligning strips, on slopes all other considerations must yield to the essential one of preserving not only the sowings but the ground itself, and there is thus no alternative but to follow horizontal contours. Otherwise the direction would be as follows:—

a. If protection has to be secured against frost and excessive insolation combined, some direction between the lines whose bearings are respectively 0° and 45°.

b. If against frost and a dangerous wind combined, some direction between a line running north-east and south-west and the perpendicular to the direction of the wind.

c. If against excessive insolation and a dangerous wind combined, some direction between a line running north and south and the perpendicular to the direction of the wind.

(iv) If against frost, excessive insolation and a dangerous wind combined, some direction between that which would be followed if only the first and second dangers acted together (case *a* above) and that which would be adopted if only the second and third (case *c*) or the first and third (case *b*) were to be provided against.

In all four cases, the strips would obviously follow most nearly the direction required by the danger that was most to be prevented.

§ 3. *Distance between the strips.*

The distance between the strips will depend—

(i) On the quantity of useful forest growth already on the ground capable of contributing, to a less or greater extent, towards the formation of the desired leaf-canopy or forest.

(ii) On the rapidity of growth, in the given soil and locality and under the given conditions of culture, of the species to be sown.

(iii) On the shape and lateral extension of the crowns of young individuals of those species.

(iv) On the requirements of those species in respect of light. Some species acquire their most useful shape and dimensions in more or less open leaf-canopy, others only on condition that the leaf-canopy is more or less complete, and so on.

(v) On the craving of those species for the early formation of a leaf-canopy, in order to be able, thanks to the mutual protection that trees standing together afford each other, to start up vigorously.

(vi) On the necessity for an early suppression of the weeds and other noxious vegetation present. Such vegetation may be harmful either on account of the rapid and invasive spread of their crowns or roots or rhizomes, or on account of the tall and dense growth they form, or of the ease and rapidity with which they multiply by means of seed or suckers.

(vii) On the object to be secured by the sowing. This object may be very various. For instance, a certain species may be absent or insufficiently represented, and it is desired to introduce it or to increase its proportion. Or, again, it may be decided to renew or to maintain in undiminished vigour a copse, that is exploited before any of its component individuals can become fertile and produce self-sown seedlings, or which is composed of of a species that cannot reproduce itself naturally from seed under the given local conditions. Or again, it may be necessary in some open situation, to raise a mere nurse, and therefore temporary, crop of some hardy and quick-growing species, in order afterwards to be able to introduce under its shelter the species which are to compose the forest permanently, but for young individuals of which the prevailing local conditions are unfavourable. And so on.

(viii) On the steepness of the ground to be sown. It is evident that the steeper a slope is, the further apart must the strips lie, in order to obviate or diminish the risk of erosion.

(ix) On the difficulty of securing success. The more casualties we anticipate, the larger must be the aggregate area actually sown and consequently the narrower the uncultivated intervals.

(x) On the amount and effectiveness of the supervision available. The less the supervision and the more untrustworthy the people exercising it, the closer together must the strips lie.

(xi) On the amount of labour that may be available or considered desirable to devote to the repair of failures.

When the area to be sown already contains a more or less open forest growth sufficiently promising to be utilised, the distauce between the strips will seldom be less than 10 feet, the maximum being about 20 feet, but the average as low as 20 feet. The intervals may be still wider if a new species has to be introduced in an already existing forest, and *a fortiori* if the proportion of an actually present species is to be increased. The intervals may be equally wide in fodder preserves, where the object of raising lines of trees or shrubs is to stimulate the production of grass. Under most of the other conditions the width of the uncultivated intervals will range from 2 to 10 feet, the more usual figure being from 4 to 6 feet.

§ 4. *Width of the strips.*

The width of the strips themselves will depend—

(i) On the tendency of the soil to be overrun with a tall or dense growth of tenacious weeds, possessing more or less invasive roots or rhizomes, or spreeding by suckers. The width would be greatest, if these weeds were shrubby.

(ii) On the rapidity with which young individuals of the species to be propagated are expected to grow up under the given conditions of soil, locality and culture.

(iii) On the hardy or delicate constitution of those individuals. The more delicate they are, the closer together must lie the sheltering edges of the bordering uncultivated intervals.

(iv) On the nature of the soil and locality. The strips will be narrow in proportion to the intensity of solar radiation, the severity of frosts, the dryness or tendency to overheating of the soil, the violence, dryness or extreme temperature of prevailing winds, &c. In cold wet soils and situations or in mist-clad localities, the strips must catch as much sun as possible and must, therefore, be made comparatively wide. So again, if the climate is mild and the soil forcing, other circumstances not being prohibitory, the strips should be given a certain width.

(v) On the light-demanding nature of the seedlings. The more shade-enduring they are, the narrower may be the strips. For instance, tun, if other circumstances permit, may be sown over the width of a hoe.

As a rule, the strips would seldom be less than 1 foot or more than 3 feet wide, the more usual width approaching 2 feet.

§ 5. *Preparation of the strips.*

When the land is open and the soil is stony and contains large woody roots, the cheapest and speediest method is to plough up the strips, the share of the plough being as broad as practicable. If the soil is naturally free and more or less clear of roots, and has not to be cultivated deep, it will even suffice to use the bullock hoe (Fig. 19), the ordinary rake-harrow (Fig. 20), or the triangular harrow (Fig. 21). Where the nature and condition of the soil and the character of the vegetation on it precludes the employment of those expeditious implements, hand tools must be used as already described on pp. 252-254; only, since we here break up a mere fraction of the total area, the soil must be more deeply and more carefully cultivated than for complete sowing. Women and children may be employed to break up the clods with mallets.

In the hills the strips should assume the form of short narrow terraces. In order to minimise erosion, the terraces should never break bond, *i. e.*, every break in each line of terraces should be exactly opposite to the terrace in the lines immediately above and below. Where the rainfall is slight and never descends in heavy showers, the terraces should slope slightly inwards, and the earth and refuse obtained in making them should be heaped up along their outer edge. Where heavy falls occur, the terraces must not be allowed to collect any water, which would ultimately flow over the edges and wash them away; hence the slope should be very slightly outwards and the refuse and superfluous earth should be collected close up against the lower edges of the terraces so as to prop them up and prevent the water flowing off those edges too rapidly or in too large volume all at once.

§ 6. *Sowing the strips.*

Owing to the restriction of the aggregate area to be sown, we can afford to use more seed area for area than in the preceding method.

The seed may be scattered or dibbled in with the hand or sown with any of the special implements described on pp. 254-255.

The seeds may be sown without any order, or according to a regular pattern, the most common forms of which are given in Fig. 92. Large seeds, in order both to economise seed and cost of transport and to facilitate after-supervision, are best sown individually in lines. For small seeds also, sowing in lines is convenient; but it is not the most expeditious method, and when the seeds germinate freely, mere scattering will suffice. In scattering the seed the workman must, owing to the narrowness of the strips, necessarily stoop and cannot therefore give his arm so wide a sweep as when sowing broadcast, so that the selection of calm and, if possible, drizzly weather need not be insisted on here to the same extent as in the other method. Small or light seed should of course be mixed with fine earth or manure.

§ 7. *Covering the seed.*

The seeds may be covered with the aid of light rollers or hand rakes or bush-harrows. When sowing machines are used, the covering will of course be effected at the same time as the sowing, but under any circumstances passing a light roller subsequently over the strips will ensure the soil being properly pressed round and over the seeds.

§ 8. *Value and employment of the method.*

As in this method only a part (from about one-third to one-sixth and even less) of the total area is cultivated and sown and a more uniform distribution of the plants is assured, it possesses the following advantages over the complete method :—

(i) It requires less labour and outlay, on which account—

(ii) We can afford to give more care and attention to the preparation of the limited area sown and to the selection and sowing of the seed.

(iii) Owing to the regularity of arrangement, supervision, from the time the tillage operations have been begun right up to the complete establishment of the sowings, is rendered extremely easy and can therefore be much more effective.

(iv) The spontaneous vegetation preserved between the strips affords considerable shelter to the seedlings on these latter, in many cases all the shelter that they ever require.

The strip method may be employed wherever direct sowing is justified, the following cases excepted :—

(*a*) Where the land is swampy, in which case it would only aggravate the tendency to damping off of the roots of the seedlings;

(*b*) Where the ground is stony or full of large roots and stools, in which case not only would the regularity of the strips be interfered with, but their preparation would be very costly or even impracticable; and

(*c*) In a very dry soil, when shade-avoiding species requiring a certain amount of moisture are used, in which case the strips would expose the soil too much.

ARTICLE 6.

TRENCH OR FURROW SOWING.

This method differs from the strip method in only two essential particulars, *viz.*, (1) that the seeds are sown appreciably below the general level of the ground, and (2) that the trenches and furrows necessarily serve as receptacles, however temporary it may be, for rain and snow water.

The first difference can exercise no qualifying effect on the application here of whatever has been said under the strip system regarding the length and direction of the cultivated lines. But the second difference makes it obligatory to follow horizontal contours in tracing the trenches and furrows, for any slope, one way or the other, of their bottom must convert them into watercourses or at least cause the soil and seeds to be washed down from the higher to the lower points and the seedlings to be exposed or entirely uprooted. In excavating the furrows and trenches the use of levelling instruments is indispensable, unless they are made in such short lengths (up to a maximum of about 10 feet) that work with the unaided eye would not result in a difference of level exceeding say 2 inches. The large wooden triangular level described on p. 220 would be a very suitable implement to use. On slopes the maximum of 10 feet should be carefully observed.

Trenches differ from furrows in that they have more or less vertical sides and are generally deeper, while the latter have more or less gently sloping sides and are deepest along the middle.

§ 1. *Width and depth of the furrows and trenches.*

In the dry soils and localities in which this system has its *raison d'être,* the growth of weeds can obviously never be heavy and every bit of whatever comes up is useful and even necessary to protect both the soil and the sowings. Hence the width of the furrows and trenches need never exceed 2 feet, and in any given case it will bear a certain proportion to their depth, which

will itself depend on the amount of moisture that they should be able to catch and hold, on the porous nature of the soil, and on the abundance of rain or other source of moisture. Actually the width will vary from 9 to 18 inches and even a little more.

§ 2. *Preparation of the furrows and trenches.*

The furrows may be made with a special plough or with a pick or hoe, according to the nature of the ground, while the trenches must be excavated with hoes and picks, even if the soil has been first of all loosened with a plough. In any case, the soil must be turned up deeper than the mere depth to be given to the furrows or trenches in order that their bottoms may offer a loose seed-bed; and to this end only the good top-soil should be put back into the excavations, the remainder being heaped up along one edge either on the side on which the seedlings will require shelter against unfavourable weather influences, or, if the ground has a pronounced slope, along the lower edge. Hence in order to economise time where picks and hoes are used, it is a good plan to put into the last made excavation the better soil obtained from the one being made. But if no portion of the excavated soil is in a sufficiently good condition to be used at once (a frequent contingency in stiff clays), the whole should be left outside for some time in order to improve under free exposure to the atmosphere. It is superfluous to add that heavy continuous rain must not be allowed to intervene between the excavation and the return of the soil, as all the looser and better portions must get washed away and be lost. All clods at the bottom of the furrows or trenches should be broken with a mallet and the soil nicely dressed.

§ 3. *Sowing the trenches or furrows.*

The seeds must be scattered with the hand and raked in, or, if they are large, they should be dibbled in with the hand to the right depth. The perambulator drill may also be used, especially in trenches. Where special protection against frost or execssive insolation or dangerous winds is required, the majority of the seeds should be sown up against that side of the excavation, on which the seedlings will need to be protected.

§ 4. *Value and employment of the method.*

The object of sowing in furrows or trenches is to secure for the roots of the seedlings immunity against drought and wide

fluctuations of temperature. The low position of the seeds enables those roots, as soon as germination has begun, to get into the deeper layers of the soil, which obviously are subject to less variation of temperature, and at all times contain more moisture, than the more superficial layers, and may remain cool and moist even when these latter have quite dried up and are intensely heated. Moreover the excavations serve as receptacles for rain and snow water, which they retain for a longer or shorter time, and this particularly during the season of most active growth. Lastly, the position of the seedlings, especially of their roots and root-collum, in a hollow affords them very effective protection against excessive insolation, frost, cold and hot winds, and hail. The method will, therefore, succeed in dry and hot or cold situations and in porous soils, where strips would at the best yield only uncertain results. But it is a very expensive one and should be employed only in exceptional cases, where less costly methods are not likely to succeed.

ARTICLE 7.

Ridge sowing.

This method is the very opposite of that just described, the seed being sown above the natural surface of the ground in soil collected into ridges. The only object to be fulfilled by the ridges is to prevent the seedlings from being submerged or from damping off from deficient root-aëration on flooded lands and in swampy situations.

§ 1. *Preparation of the ridges.*

The length and direction of the ridges are regulated by the same considerations as the corresponding points in the strip system, except when, as described lower down, they immediately flank trenches intended to catch and retain surface drainage, in which case they must necessarily follow horizontal lines and for convenience and rapidity be broken up into short lengths like trenches and furrows (see p. 256). The height of the ridges must be limited to the minimum figure that would secure the necessary amount of aëration for the roots of the seedlings. Their width cannot be less than what is necessary, having due regard to their height, for their stability, and it must not exceed the figure beyond which the roots would suffer from insufficient aëration. Actually the ridges will seldom be more than 18 inches across at the base and from 9 inches to 1 foot high.

The ridges may be made either (1) by drawing together the top-soil in lines or (2) by digging a trench and piling up the excavated earth along one edge of it. In the second case, the dimensions of the ridges may be diminished in consequence of the adjoining trench, which can also serve as a drain or as an irrigation channel or as a depression to hold water, if any rain should fall during the dry season. When the trenches serve as drains, they should be made on that side of their sister ridges towards which the ground slopes. Otherwise they should be excavated on the upper side so as to give to the seeds and seedlings in the ridges the full benefit of the water they contain, to enable them to catch as much of the surface drainage as possible and to prevent the ridges from being breached or washed away by that drainage. Whether trenches are made or not, the earth forming the ridges should be carefully consolidated by beating it firm, and if practicable, also by turfing their sides. In the great irrigated Changa Manga plantation the ridges are made with earth excavated from trenches which are 1′ × 1′ in section and serve as distribution channels. In the reboisement of the Pabbi, in the Gujranwala District of the Panjab, the trenches serve to catch the surface drainage and are given a section of 1′ × 1′ on merely inclined ground and of 2′ × 2′ on slopes of 25° and upwards.

On very swampy land each ridge may occupy the whole width between two consecutive drainage cuts, and be formed with soil taken half from each of the two cuts. The ridges will in that case be necessarily more or less flat-topped.

§ 2. *Sowing the ridges.*

The seeds may be dibbled in along the top or along the sides or along both the top and sides. When a trench flanks each ridge, the seeds should be sown only on the side overhanging the trench, particularly if this latter is intended for irrigation or for catching and holding the surface drainage. Otherwise the top of the ridges must be sown, and if the seeds are also dibbled along the sides, it will be with the object of consolidating the sides when turfing is dispensed with, and also of protecting the seedlings higher up better than turf or mere grass could do.

When the ridges occupy the entire interval between two drainage channels, the top may be expeditiously sown with the perambulator drill.

§ 3. *Value and employment of the method.*

The method of sowing on ridges is especially adapted where irrigation is available and on the innumerable dry slopes we have in India; also in the several taráis and other swamps in different parts of the country. In nearly every case it is advantageous, and in the majority of them even necessary, to flank the ridges with trenches. Besides serving as drains or irrigation channels or receptacles for holding water, the trenches catch a very large proportion of the surface drainage when rain falls and thus diminish the risk of erosion on unstable slopes and on land liable to get ravined. The method is costly and should, therefore, be adopted only after the chances of other more economical methods have been fully weighed and considered.

ARTICLE 8.

COMBINATIONS OF STRIP, RIDGE AND TRENCH.

The following combinations are possible:—(1) ridge with trench or furrow; (2) strip with trench or furrow; (3) strip with ridge; and (4) strip with trench or furrow and ridge. For convenience of expression, in the rest of this article, the words "or furrow" will not be repeated, and must be understood each time the word "trench" is used.

§ 1. *Combined ridge and trench sowing.*

In studying ridge-sowing we have already considered the case of a combined ridge and trench, in which only the ridge was sown. The only difference between that system of ridge sowing and the present method is that here the trench also is sown. It is evident that the trench can in this case never partake of the nature of a drain.

Sometimes both ridge and trench are sown with the same kind of seed, so as to secure a double chance of success; if the sowings on the ridge fail, those in the trench at least are likely to succeed, and *vice versâ*. Such a procedure is of course nearly always a *testimonium paupertatis*; but in this country, for many years to come, all our work must partake to a certain extent of an experimental character, and even when our knowledge of forest conditions in India has been perfected as far as human perfection can go, it will often be advisable to protect ourselves against contingencies and sow both ridge and trench.

But more often it will be seeds of different species that should be sown in the two places, by which means the chances of success will be in the highest degree assured. It is evident that the more delicate species will be sown on the common side of the ridge and trench and at the bottom of the trench, the hardiest being kept on the top of the ridge.

A special variety of the system would be to combine a forest and an agricultural crop, the latter being sown along the top of the ridges in order to protect the former. By this means the cost of preparing the ground may be wholly or partially recouped, and delicate forest species may be propagated. It is evident that the agricultural crop chosen should be a hardy one for the locality and not be invasive. For north-western Indian the *Cajanus indicus* would be very suitable; where frosts do not prevail, the castor oil plant; and so on.

Whenever, outside swampy localities, the simple ridge system gives good results, the combined ridge and trench will generally succeed better and even very much better, especially on dry hill-sides, and may be adopted without any extra cost except that of seed and of sowing the additional quantity of seed.

§ 2. *Combined strip and trench sowing.*

The trench serves the same purpose here as in the immediately preceding system, while the strip is better suited than the ridge in dry soils and for species that cannot stand drought. On hill-sides the excavated soil from the trench will go to help in forming the terrace-like strip on the lower side of the slope, while on more or less level ground it will be used in filling up adjoining depressions, and thrown across the line of drainage so as to enable the trenches to fill even with a moderate shower. As in the preceding system, an agricultural crop may be sown with the forest seeds, in which case each strip will generally occupy the entire interval between trench and trench.

§ 3. *Combined strip and ridge sowing.*

This combination will always be an extremely rare one and may occur only in the following three cases :—

(i) When on a hill-side there is no danger of erosion and the strips are made with an inward slope, the refuse earth being thrown up on the lower side in the form of a ridge.

(ii) When fields divided up by ridges into small compartments are to be brought under forest, in which case the ridges would

generally be sown with forest seeds and the flat enclosed land with a forest and field crop combined.

(iii) In very wet land, where the ridges are made by drawing together the adjacent topsoil from only one side.

§ 4. *Combined strip, ridge and trench sowing.*

We may have three modes of combination:—

(i) The trench running between the strip and ridge, the last being of course on the side the ground falls. This is the best of the three combinations for ground that is not much inclined, as the water held by the trench will benefit ridge and strip equally and seedlings of delicate species in the trench will be well protected both against weeds and injurious weather influences. On a decided slope the loosened soil of the strip would get washed away into the trench.

(ii) The ridge separating the trench from the strip, the last being on the side towards which the ground falls. This is obviously the best of the three combinations for land with a decided slope. Owing to the inclination of the ground the water from the trench must flow through the soil downwards to the strip.

(iii) The strip separating the trench from the ridge. This combination should never be adopted, for under the most favourable circumstances the ridge can get very little benefit from the trench, and *vice versâ.*

The use of the treble combination treated under this head is more so than that of any of the preceding, a *testimonium paupertatis*; but with it the chances of success are of course singularly increased. The system is obviously very costly and must be avoided, except in case of absolute uncertainty as to the best method to adopt. Under any circumstances it should never be employed on any extensive scale, but merely experimentally in order to gain experience. Its use is quite of the question on slopes of 15° and upwards; and hence it is always possible and advisable to raise a field crop on the interval between each triplet so as to recoup at least part of the total outlay.

ARTICLE 9.

Patch sowing.

If we break up strips into lengths so short that each length becomes more or less square-shaped, we obtain *patches.* Patches, may, however, also be circular, but the square is the easier shape to prepare and is the one generally adopted. Patches may hence

be defined as little squares of cultivated soil arranged in more or less parallel equidistant rows or *lines* and at equal distances apart from one another in each line.

§ 1. *Distance between the patches.*

Thus in making the patches there are two distances to be considered, (1) that between the lines and (2) that between the patches in each line. The former distance is regulated by the very same considerations as the width of the uncultivated interval in the strip system; the latter also by the same considerations, but with this qualifying circumstance that allowance must be made for a patch or two failing here and there and thereby increasing the interval between the consecutive patches in one and the same line. Hence the patches are generally arranged closer together in one direction (in the lines) than in the other (from line to line). In practice we usually provide for the failure of every alternate patch and thus make the distance between the patches in the lines half the distance between the lines. Sometimes, however, as when there is already some useful forest growth on the ground or grass is a valuable commodity, and so on, the distance required between the lines may be so great that a given absolutely small number of casualties may seriously compromise the success of the sowings. In that case half the distance would be too much and the ratio must be accordingly diminished in proportion to the extent to which failures are to be apprehended.

§ 2. *Direction of the lines of patches.*

The lines of patches differ from the lines of strips by the circumstance that the dimension of the patches in the direction of the lines is obviously never anything so considerable as the length of a strip, and is always small enough to afford complete protection against winds and excessive insolation and radiation as long as the seedlings do not top the surrounding spontaneous vegetation. Hence until that stage is reached it is of no consequence at all, as far as injurious atmospheric phenomena are concerned, in what direction the lines run. It is only when the seedlings have grown up that they form a series of parallel lanes, along which the wind may sweep with unchecked violence if the directions are coincident. In the plains, therefore, it is quite sufficient to run the lines of patches at right angles to the direction of dangerous winds.

In the hills the lines of patches should of course, whenever possible, follow horizontal contour lines, irrespective of every other

consideration. But when the ground is so steep and bare of trees or shrubby growth as to afford no foothold or support for the the workmen, each patch would require a ledge to be cut immediately below it for the workman making it to stand on. If the lines of patches were close enough together, each line would serve as a *point d'appui* for the preparation of the line next above it. But it may not, on account of the expense or for any other reason, be possible to have the lines so close together. In that contingency the lines of patches should run up and down hill, but making an appreciable angle with the lines of steepest descent, and the workmen would then work upwards from the lowest edge of the area, each individual having his own line and using the patch last made as a foothold for the preparation of the immediately higher patch.

§ 3. *Size of the patches.*

The dimensions of the patches are obviously amenable to the same considerations as those which regulate the width of strips; but as in the strips the seedlings can receive extraneous shelter only on two sides, whereas here they receive it equally on every side, the cross dimension of the patches may safely exceed the width that would be given to strips under identical conditions of soil, locality, species employed and surrounding vegetation. One of the rare exceptions to this rule will occur when on steep slopes the lines of patches run up and down hill. In that case, to minimise the chances of erosion, the patches should be as small as other considerations will allow. No danger need be apprehended for the seedlings in these small patches from the surrounding vegetation, which on such steep slopes is seldom dense save under standing forest. In the exceptional case just referred to, the side of the patch will vary from 1 to 2 feet, otherwise it will generally range from 2 to 4 feet, from 2 to 3 feet being the most common dimension.

§ 4. *Preparation of the patches.*

In preparing the patches the use of any but hand-tools is of course out of the question, although no doubt, before the making of the patches is actually taken in hand, the ground may under favourable circumstances be ploughed or harrowed or hoed-up in lines coinciding with the lines of the future patches. The digging and grubbing tools would be the same as those used in making strips. As the patches obviously aggregate a much small-

er area (roughly one-half to one-third) than what would be cultivated under the strip system, the soil in each patch should generally be prepared more deeply and much more carefully than they would be in strips, and, in some cases, may even be manured. When, on flat ground, only small patches are required and weeds are not heavy and the soil is neither stony nor full of strong roots, the patches may be prepared with the torsion rake (Fig. 93).

§ 5. *Sowing of the patches.*

The sowing should obviously be thicker than under similar conditions in strips. When the seeds are small, a pinch of them may be scattered with the hand and covered over with the aid of a light rake or brush of twigs. If the seeds are large enough to be sown regularly, they should be put into the ground according to a fixed pattern, which will of course be different according to the size and quality of the seeds, the prevailing conditions of soil and climate, the nature of the seedlings produced and the object to be accomplished. The seeds may be dibbled in with the forefinger and thumb or with a small dibber; but a much simpler, neater and expeditious plan, which also ensures the most perfect uniformity of distribution and depth of sowing, is to use a strong board of the same size and shape as the patches and studded on the lower side, according to the given sowing pattern, with pegs or spikes long and thick enough to make holes in the soil of the required depth and diameter. The other side of the board should be furnished with some sort of convenient handle, with which to carry about, maneuvre and steady the board. The board being placed accurately on a patch, is pressed or trod upon until the entire length of the pegs or spikes is buried in the soil. On removing the board, nothing more remains to be done than to drop a seed into each hole, with a little manure added if necessary, and then to rake the soil lightly over the seeds It is best for one workman to manipulate the board and another to sow and cover the seed. The use of the implement just described, which may be termed the *sowing porcupine*, furnishes several important advantages. In the first place, there is no time lost in counting the seeds and in distributing them uniformly, and any untrained or careless cooly can sow with it just as efficiently as the most experienced or conscientious workman. In the second place, it allows each future seedling to be effectively manured with the smallest possible expenditure of labour and of manure; and the sowing being well

done, less seed need be used. Lastly, owing to the perfect uniformity of the sowing holes secured with the implement, seeds of different species can be sown in each patch in accordance with the habits and requirements of the several species, and check and supervision are remarkably facilitated. For the board we may substitute a piece of sheet iron strengthened with ribs or an assemblage of battens or iron bars.

§ 5. *Value and employment of the method.*

This method of sowing, while it enjoys all the advantages possessed by the strip method, is superior to the latter in the following respects:—

(i) By it a much smaller proportion (from about one-seventh to one-twelfth and even less) of the total area is cultivated and sown; wherefore

(ii) Less labour and time are expended;

(iii) More time, skill and care can be devoted to the preparation and sowing of the cultivated portions;

(iv) Less seed is used (under ordinary circumstances only one-half), thus justifying stricter selection and thicker sowing; and

(v) Outlay of money is diminished. Moreover

(vi) Supervision and examination of results, the work being done at well-defined points, are easier;

(vii) The young crop receives more protection from the surrounding spontaneous vegetation, which borders it on every side; and

(viii) The chances of erosion on hilly ground are diminished.

The patch method is peculiarly well adapted for stony localities or where the ground is traversed by numerous strong and woody roots or where the soil varies very appreciably from point to point, also in repairing small areas of previously unsuccessful regeneration. It is, however, totally unsuited for wet or swampy localities, since each patch would there become a collecting centre for the superfluous moisture. Moreover, it is not effective enough in the midst of a strong growth of weeds and undershrubs.

ARTICLE 10.

PLOT SOWING.

Plots are simply patches of an exaggerated size, which renders their employment practicable and advantageous under ordinary standing forest where the growth of weeds and brushwood is very

heavy, as in evergreen forests and in the Himalayas. The size of the plots (from 6 to 10 feet side) permits of their being made at much wider intervals apart than patches, from about 100 to only 40 plots per acre, and then they constitute numerous small temporary nurseries from which the intermediate ground can be planted up. For this reason they are extremely useful on hill sides containing several distinct zones of vegetation or in forests where the soil and locality, and consequently also the composition of the stock, vary from point to point, and especially to increase the proportion of some valuable species that cannot reproduce itself naturally with the same ease and abundance as companion species of much less value.

It is hardly necessary to add that the soil in the plots must be completely freed from roots and rhizomes capable of throwing up shoots and thus enabling undesirable species to again take possession of the ground. Moreover the cultivation should be deep and thorough in order to give the sowings the best chance of establishing themselves. If the soil is poor or otherwise of bad quality, it should be well manured. The proportion actually cultivated of the total area will be so small (never more than 10 per cent), that the extra cost of high tilth will be trifling, especially when compared with the results. The sowing should be thick enough to enable the seedlings to close over the ground within 4 to 6 years.

ARTICLE 11.

PIT OR HOLLOW SOWING.

The *pit* and *hollow* are to the patch what the trench and furrow are to the strip, and a pit differs from a hollow in the same sense as a trench differs from a furrow, that is to say, a pit has a flat bottom and more or less vertical sides, while in a hollow the sides slope gradually from all four sides towards the middle, which is therefore the deepest portion.

The dimensions, including the depth, of pits or hollows are influenced by the same considerations as those which determine the width and depth of trenches or furrows; but just as the cross dimension of a patch generally exceeds the width of a strip, so the cross dimension of a pit or hollow may exceed the width of a trench or furrow.

Pits are prepared with similar tools and in the same way as trenches, only in their case the rubbish may be heaped up along

several sides, according to the several quarters on which shelter may be required. Hollows may also be prepared with the same tools as pits, but where the soil is neither stony nor full of strong woody roots, they may be expeditiously made with soil augers (Figs. 94 and 95), with which the soil can be loosened to a much greater depth and more thoroughly than with picks or spades or hoes. The soil at the bottom of the pits may be loosened in the same way, and both in pits and hollows a top-dressing of manure may be given."

Pits are more expensive than hollows, which indeed cost very little more than patches, and may in the plains of India be employed, with even superior results, in nearly every case in which these last succeed. In a hollow, the tools reach and work up a deeper layer of the soil than in a patch, the young plants are better protected against drought, insolation, frost and injurous winds, and, thanks to the sloping sides, the seeds are severally placed under various conditions, so that the chances of success are multiplied. Pits should take the place of hollows only in very dry or frosty or hot, stony localities, or when the upper soil forms a hard pan, through which the delicate roots of young seedlings cannot work their way before they get beyond the reach of drought. Pits and hollows possess all the advantages over trenches and furrows which patches possess over strips, and they are, even more so than patches, out of place in wet soils. Pits worked deep and filled with manured soil would answer capitally in grass lands in the case of hardy species, like sissu, sal, *Hardwickia binata*, &c., the yearling of which sends down a long thin tap-root, or in that of delicate but fast-growing species, which, like tun, grow all the better for some protection given to the root-collum and the lower portion of the stem.

ARTICLE 12.

Sowing in Holes.

Holes are simply pits of reduced diameter (from 2 to 5 or 6 inches), but in which the soil is generally loosened to a great depth (from 2 to 4 feet and even more), in order to enable young seedlings to at once send down their roots beyond the reach of drought and injurious extremes of temperature, or through a stratum of soil that is either impenetrable to their roots or is choked up with the rhizomes and roots of strong grasses. This rapid extension of the roots into good or unoccupied soil secures

the early establishment of the seedlings, and the narrowness of the holes protects the base, or most sensitive part of their stems, with the collum buds it contains, from weather extremes.

The holes may be made with soil augers (Figs. 94 and 95) or the borer represented in Fig. 96, if the soil is not stony; or with a strong boring machine or with crowbars, if it is stony. In filling up the holes good topsoil may be used, or a few inches of manure may be put in last of all, in which the seed may then be sown.

Where the growth of weeds is very strong and dense, the pit may be combined with the hole, that is to say, after making a pit in the usual way, a hole may be bored in the centre. By this means the seedlings will be protected from being choked up both above and inside the soil as long as they are still small and unable to struggle successfully with those weeds.

This method of sowing is no doubt costly, but it gives a certain chance of success to the seedlings and more than repays in the end by saving heavy after-expenditure on repairs and maintenance and by the accelerated establishment and growth of the young plants. It ought to give excellent results with species, which, like teak, cannot suffer close contact with strong weeds, especially the grasses, or which like sal, sissu, *Hardwickia binata, &c.*, do not get established until they have developed a long, deep-seated taproot.

ARTICLE 13.

MOUND SOWING.

Mounds are to patches and pits what ridges are to strips and trenches. As plants growing up on mounds enjoy root aëration on all four sides, whereas those on ridges receive it on only two sides, both the height and base of the mounds may exceed the corresponding maxima figures for ridges. Hence mounds may stand up to 2 feet high and even more, and measure from 2 to 4 feet across at the base. The alignment and spacing of mounds are determined by the same considerations as the alignment and spacing of patches. As in the case of ridges, the sides of mounds should be turfed or otherwise consolidated.

The mounds may be built up by drawing together the surface soil or by using soil from excavations made alongside. In the latter case, the excavations serve as drains and thus contribute powerfully towards root-aëration. In localities where the soil, although water-logged during the rains, becomes very dry during

the rest of the growing season, the excavations will catch from occasional showers enough water to keep the plants alive and vigorous. The excavation may consist of a single square pit on one side of each mound, or of two pits, one on each of two opposite sides of the mound, or lastly of a sort of continuous ditch or moat all round the mound, according to the degree of swampiness to be corrected. The excavations help to reduce cost by making it possible to diminish the height and generally the size of the mounds.

Sowing on mounds constitutes *par excellence* the system to be followed in very wet soils, where the mounds would not only be far more effective than ridges, but also cost very much less. Mounds cannot, however, supplant ridges in irrigated areas that are not flooded.

ARTICLE 14.

COMBINED PATCH, PIT AND MOUND SOWING.

As in the case of continuous cultivated lines, four different combinations are possible:—(1) pit and mound, (2) patch and pit, (3) patch and mound, and (4) patch, pit and mound.

The first combination offers the same characteristics as the combined ridge and trench, with this difference that it costs less; but it is impracticable in irrigated land, where the water is not abundant enough to allow of flushing, and is not so effective on hillsides.

The second combination would replace the first in dry flat localities.

The third combination is a very rare one, its employment being perhaps limited to the propagation, in the middle of a circular fringe of some moisture-loving, sheltering-affording plants, of some delicate species, for which the soil is actually too wet to admit of its being sown anywhere but in raised soil. In the case in question, the prepared ground at each point will consist of a plot or a large patch with a mound standing up in the middle.

The fourth and last combination is a very awkward one and should never be used, except it be on a very limited scale as a temporary expedient when starting work under entirely unknown conditions. After a very short time experience would show which element of the triple combination was superfluous and should be omitted in extending the sowings rapidly over the remainder of the area.

SECTION V.

Quantity of seed to sow.

We are now in a position to appreciate the quantity of seed to sow in any given case. It will depend :—

(i) *On the quality of the seeds, i.e.*, the percentage that are expected to germinate, the average time in which they are likely to complete their germination, and the vigour of the seedlings it is believed they will produce.

(ii) *On the method of sowing employed.*—Thus complete sowing without tilth will require most seed; then follow, in descending order, complete sowing with tilth, combinations of strip-trench-ridge, strips, trenches, ridges, combinations of patch-pit-mound, patches, pits, mounds, holes, and lastly plots.

(iii) *On the state of preparation of the soil.*—The better prepared the soil is for the germination of seeds and the development of the seedlings, the fewer will be the casualties, and hence the sparser need be the sowing.

(iv) *On the nature of the soil and locality.*—The drier the soil is, or the heavier the growth of weeds, or the severer the climate, and so on, the earlier should the leaf-canopy be formed and the thicker must, therefore, be the sowing.

(v) *On the special risks, independent of the soil and the locality, to which the seedlings are liable to be exposed.*—Such are depredations of rats, pigs, deer, insects and other animals, night-frosts, &c.

(vi) *On the nature and habits and requirements of the species to be propagated.*—For instance, the profuseness of the sowing will be in direct proportion to the delicate nature of the seedlings, their slowness of growth, the narrowness of their crowns, the difficulty with which natural pruning takes place, and so on.

(vii) *On the most advantageous density of growth under the given circumstances.*—A too dense or a too open growth are equally harmful. In the former case, the expenditure is needlessly increased by the larger area cultivated, by seed wasted, and by thinnings rendered necessary before the individual stems become marketable, while the crop itself suffers deterioration owing to the weedy growth of the component trees, the ultimate result being loss of production. In the latter case, the leaf-canopy

forms too late either to protect the soil or to protect and draw up the component stems; and costly repairs become necessary to replace the numerous casualties, and loss of production again occurs.

(viii) *On the object to be fulfilled by the sowings.*—Thus sowing should be profuse, if tall trees with long straight, clean boles are desired; more or less sparse, if the object is only to fill up small blank intervals in the midst of existing forest, or to introduce or increase the proportion of a certain species, or to obtain timber of large girth early; and so on.

Absolutely speaking and having due regard to all the conditions just enumerated, the quantity of seed to sow should be sufficient, according to the severity or mildness of the climate, the dryness or humidity of the soil, and the delicate or hardy constitution of the seedlings, to produce a complete leaf-canopy within a period ranging from 5 to 10 years after the sowing.

SECTION VI.

Maintenance operations.

At first, until germination has taken place, the seeds sown will require to be specially protected, and after that, while the sowings are establishing themselves, the seedlings will have to be protected, their growth directly encouraged and casualties immediately repaired.

ARTICLE 1.

PROTECTION OF THE SEEDS SOWN.

As long as the seeds have not germinated, they are liable to be eaten up by animals or killed by unfavourable weather influences during the process of germination.

As regards the various animals that devour seed, sowing at the right time often diminishes their ravages, if it does not entirely save the seeds. Thus, in the Himalayas, seeds sown just before snow falls, are effectually protected against insects, rats and most other predatory animals. And, in a general manner, it may be said that the shorter the time during which the seeds are allowed to lie before germination is completed, the better for their safety. Seeds sown at the beginning of the season of vegetation should undergo a little forcing. If the area to be sown is infested with rats, pigs should be allowed to run over it or owls and non-venomous rat-eating snakes should be encouraged. If birds are troublesome,

they ought to be scared away by men armed with guns and moving about continually. There are some seeds the embryo of which, even after germination has begun, takes some time to come out of the testa. In this condition the embryo becomes sweetish and is attacked by small ants. Such seeds, besides having their germination forced, should be soaked in a solution of some drug avoided by those insects.

Among unfavourable weather influences, if every possible precaution has been taken to sow at the right time, drought is the only one to be feared, and against it we are helpless, unless we can irrigate or water. If in spite of every precaution, the seeds first sown have been killed on any large scale, our only resource is to sow again at once, if a sufficient period of the season of vegetation is still remaining.

ARTICLE 2.

PROTECTION AND SPECIAL FOSTERING OF THE SEEDLINGS.

PROTECTION AGAINST ANIMALS.—It is impossible to secure complete immunity against animals. Grazing should of course be rigidly excluded, even at the expense of putting up fences. Against destructive game no false scruples regarding sport should deter us from exterminating them, whether they are quadrupeds or birds. Where deer and antelope are numerous, the cultivated lines, whether continuous or not, are liable to be converted into their regular tracks; in which case, besides browsing off the tender succulent shoots, they trample down or break young seedlings. To minimise this danger the cultivated places should be made as inconspicuous as other governing conditions will allow. This precaution also reduces the depredations of rats, which always like clean soil, and diminishes the numbers of insects, many species of which frequent principally warm sunny spots where the soil has been loosened. Insectivorous birds and other animals should be encouraged.

ARTICLE 3.

PROTECTION OF THE SEEDLINGS.

PROTECTION AGAINST FROST.—A simple and cheap method of securing this protection is, if the seedlings are small enough, to put conical grass shades (Fig. 97) over them. The shades should be strong enough to withstand wind and rain, and must let in sufficient light, air and warmth to prevent the plants from

sickening. The way to afford the seedlings the maximum amount of heat, while at the same time protecting them from the morning sun is to keep the shades slightly open on the south-west side. If the grass surrounding the seedlings is tall and not too far away, it should be brought together over each seedling or group of seedlings and tied up in a knot at the top. Indeed, if the vegetation on the uncultivated intervals is full and dense enough and stands well above the seedlings, there is nothing to be done but to let it stand as it is, or, at the most, it may be slightly bent down over them. If the frosts are not severe, it will suffice to earth up the base of the seedlings in order to protect the buds in the vital region of the root-collum. Lastly, if the seedlings are too large to be protected by the surrounding vegetation or by means of grass shades, grass may be tied up or coiled loosely round the stems and main branches of the seedlings, and especially over the end of the leading shoot. But when frosts are very severe, the only way to obviate complete failure is to sow none but really hardy species, at the outset at least.

PROTECTION AGAINST EXCESSIVE INSOLATION AND DROUGHT.—All the measures detailed under the preceding head answer here also. But, as a rule, the sun alone is very far from being so great a danger to seedlings as frost, and, in most cases, no special precautions against it are necessary, and the shade cast laterally by the vegetation standing on the uncultivated intervals generally suffices. It is chiefly in the case of yearlings, and particularly of young seedlings belonging to species that come into leaf at the beginning of, or just before, the hot weather, such as, for example, sal, sissu, tun, &c., that excessive insolation is to feared in exposed places and must be provided against. Timely watering is always the best precautionary measure. During the season of dormant vegetation the seedlings require no help; either the air is then too cold for drought to occur or the young plants are leafless and cannot possibly suffer from over-transpiration. During the summer rains it is seldom that such long droughts occur as to necessitate watering, and this too happens almost exclusively in the dry zone receiving a rainfall of less than 20 inches. It is only during the October-November heats, which prevail outside the area subject to the influence of the N. E. monsoon, that yearlings generally begin to sicken and may require to have the soil kept moist round them. After these five or six weeks of danger, the activity of the young plants sinks to a minimum and the nightly dews caught and retained in a loose soil generally

suffice, especially in northen and central India. But during these five or six weeks of extremely bright sunshine and a very nearly saturated atmosphere, it is often the over-active transpiration of the green parts, far in excess of the amount of moisture taken up by the roots from a cold soil, that hurts the young plants* rather than the absence of sufficient moisture in the soil; and the best safeguard is to shade the plants. From December to February inclusive, the activitiy of the young plants sinks to a minimum or entirely ceases, and so it is only where there is no true winter that the nightly dews may not suffice and thus require to be supplemented by one or two waterings, such a contingency being, however, extremely rare. After February most of our trees outside the Himalayas begin to be leafless and remain so until the burst of the S. W. monsoon. Seedlings of such species will hardly need to be watered then, and it is only young plants of species that come into leaf in spring that may have to kept alive by one, or at the outside two, good waterings, while the new leaves are still tender and wanting in firmness. Of course one of the most effective means for avoiding, or at least minimising, the labour and expense of watering is to get the seeds sown to germinate early in the summer rains (or in the Himalayas, if late frosts are not to be feared, as early in the spring as possible), so that, by the time the beneficial influence of that season has passed away, the seedlings may be strong and deep-rooted enough to have little or nothing to fear from drought or over-transpiration.

PROTECTION AGAINST DANGEROUS WINDS.—Against this danger we require only lateral protection and that too generally on one side only, *viz.* the quarter from which the wind blows. If the spontaneous vegetation standing on that side is tall and dense enough, any further precaution will rarely be required. Otherwise the base of the seedlings should be earthed up and any one of the other measures recommended against frost adopted as an additional safeguard, which may, in the case of hot winds, include also watering.

ARTICLE 3.

SPECIAL FOSTERING OF THE SEEDLINGS.

We may specially foster the growth of the young plants by

* May it not be to this cause that we must attribute most, if not all, the failures in sowing and planting at Darjeeling.

watering them, and by weeding and hoeing and manuring the soil round them.

§ 1. *Watering.*

We have already seen that water may have to be given to the seedlings to save them from drought. But even where watering is not essential and the seedlings can be kept alive without it, it may well happen that the cost of the operation would be more than compensated by the consequent accelerated growth of the young plants. If such be the case, wherever irrigation is practicable within the limits of econony, it should be employed without hesitation; otherwise there is no alternative to handwatering.

Whatever is done, mere superficial watering should be avoided. On this account handwatering should be effected in one of three ways: either (i) a hollow a few inches deep should be made round each seedling and the soil in it loosened before each operation or (ii) a hole of the right depth should be bored obliquely on one and the water poured therein, or (iii) an amphora-shaped porous, earthenware jar should be buried on one side of each seedling and filled from time to time. In the last case the downward taper of the jar has this advantage that a given quantity of water stands at a higher level in it than if it had a broad base, and a large capacity is secured without making the vessel too long.

The number of times water should be given will depend on the nature of the soil and locality, the requirements of the species, and the mode of watering. During the season of dormant vegetation, which season will vary with the locality and the species, the plants need not be watered. Nevertheless, if that season coincides with the hot weather, watering is bound to shorten it both by making it begin later and end earlier and in certain cases it may reduce it to only a few weeks or even a few days. But as watering is nearly always very expensive, it should, as a rule, be limited to the following three cases, whenever the attendant outlay is not prohibitory:—

(i) Supposing vegetative activity, beginning with the summer rains, continues throughout the cold weather and does not cease until the setting in of the hot weather, the season of repose might be delayed by watering towards the end of the cold and the beginning of the hot weather, so as to strengthen the seedlings in order that they might make a sudden vigorous start at the commencement of the next summer rains.

(ii) Supposing that vegetative activity starts afresh in spring and continues right up to the summer rains, ceasing only with the commencement of winter, a copious watering may be given just when the new foliage is due, so as to help the seedlings to make a good start, and the operation may be repeated during the hot weather each time there was any sign of languishing vegetation.

(iii) In every case on the occurrence of long breaks during the first half of the summer rains, in order to maintain a continuous development of the year's shoots.

§ 2. *Weeding and hoeing, and manuring.*

WEEDING AND HOEING.—The removal of weeds is always beneficial and generally necessary during the growing season, especially during the first part of it, from May to August in the Himalayas, and from June to August elsewhere. After August scarcely any new organs are formed above ground, the vigour of the seedlings being confined chiefly to the continued development of the roots, the lignification of the newly formed parts above ground, and the storing up of reserve material for the next season's start of growth. All these three processes are of course favoured by the absence of weeds, and, if the weeds are not required as a protection against injurious weather influences, it would be an error not to remove them, if the necessary labour and money are available. But the processes in question are only weakened, not entirely checked, by the presence of a certain mass of weeds, and, provided free growing room both in the air and in the soil is given during the first part of the season of vegetation, the seedlings will practically suffer nothing by the presence of weeds in their midst during the rest of the year: at the worst their final establishment may be delayed by a year or two.

The amount of space to clear round the seeldings will depend on their habits and requirements, the more or less invasive nature of the weeds, the suitability of the soil and locality, and the character of the climate. The more shade-avoiding or hardier or rapid-growing the seedlings, the more invasive the weeds, the more suitable the soil and locality for the species sown, the milder the climate, and so on, the more free growing-room must be given to the seedlings both in the air and in the soil. Generally speaking, it is seedlings that develop a long tap-root with a few short and thin side roots which suffer most from contact with weeds in the soil; *e.g.*, teak and sissu; and the most dangerous weeds are those

which come up in close contact with the seedlings, which they deprive of air and light above ground and rob of nourishment underground. Such weeds should if possible, be pulled up by the roots. Those further away are really only a prospective danger, and may in most cases be prevented from becoming an imminent one simply by being cut back level with the ground or to any required height with a sickle. or merely broken and bent back outwards. Shrubby vegetation is most to be guarded against, and after that, amongst herbaceous plants, tall dense perennials.

At the same time as the soil is freed from weeds it may also be loosened. The advantages of a loose layer of soil at the surface are as follows :—

(i) Heavy deposition of dew in the interior during the cold weather.

(ii) Free root-aëration.

(iii) Admission of carbonic acid, ammonia and nitrous and nitric acids with the oxygen-containing air into the interior and consequent loosening and enrichment of the soil there.

(iv) Exclusion of sudden changes of temperature, thanks to the non-conducting cushion of air in the loosened layers.

(v) Consequent impediment to evaporation ; hence preservation of the moisture in the inferior layers.

(vi) As a consequence of the preceding effects, encouragement of vigorous extension of the roots, especially in a downward direction.

Such being the case, it is evident that this loosening of the soil will have most effect during the season of vegetation, while the root-apparatus of the seedlings is absorbing water energetically and actively extending itself and the growing parts above ground are making their heaviest demand on it.

As loosening the soil necessarily clears it of weeds, and *vice versâ*, the two operations should, for economy's sake, be combined into one. The combined operation will always be called for at the commencement of the season of vegetation, and may be repeated at any other time during the course of that season, provided other prevailing circumstances permit of it.

MANURING.—It will seldom be practicable to manure the seedlings. But whenever that operation is possible and justifiable, a top-dressing of manure should be given at the commencement of the season of vegetation, at the same time as the combined weeding and hoeing up of the soil round the seedlings is effected.

ARTICLE 4.

REPAIRS.

Wherever seeds have failed to germinate or seedlings have died off, causing blanks that can never cover up at all or would be too long in being covered up by the meeting of the crowns of the surviving seedlings, there it is necessary to introduce new seedlings. This may be done either by sowing seed again according to any of the methods already described, or by means of planting, about to be treated in the following Chapter. When to sow and when to plant will be explained in Chapter VI; but it may be laid down as a general rule that, if no change of species is contemplated, seed will usually be sown in place of seeds failing to germinate, or of yearlings or two-or, at the outside, three-year old seedlings dying off, transplants being put down in every other case; and if new species are to be introduced into the blanks produced by the failures, the question of sowing or planting must be decided in accordance with the considerations discussed in Chapter VI.

SECTION VII.

Sowings of more than one species.

In describing the use of the sowing porcupine (p. 273) allusion has already been made to the sowing of more than a single species. It may be necessary to sow more than one species either because it is advantageous to grow a mixed forest, or because the species is so delicate or so slow-growing that some one or more other species must be raised simultaneously with it, or just a little in advance of it, in order to nurse it until it is strong enough to take care of itself or to assist it in protecting the soil until it is sufficiently advanced to fulfil that object unaided. Thus three distinct cases of mixed sowings present themselves.

In all three cases the seeds of the several species must be mixed together in the right proportions if they are to be sown broadcast. But if the sowings are to be effected in regular lines of strips, patches, &c., it is only when the single species to be permanently maintained is extremely delicate or shade-enduring, or the locality to be sown is exposed to very severe weather influences, that the seeds may be thus mixed together; otherwise the different species should generally be sown in separate lines.

In the case of a permanently mixed forest having to be raised, sowing in separate lines would have the following advantages:—

(i) The different species would not be in each other's way and the stronger species could be easily prevented from suppressing or even merely keeping back the weaker species.

(ii) Supervision would be easy.

(iii) In repairing casualties we would know exactly what species to sow or plant, and where and in what abundance.

(iv) Cleanings and thinnings (to be treated of in Part III) would be singularly facilitated.

(v) As a consequence of the preceding advantages the maintenance of the mixture, in the correct proportions according to the age of the crop, would never present any difficulty.

The reason for generally sowing in separate lines, even when only temporary help from other species is required in forming the leaf canopy, is evident, for otherwise the usually more rapid growth and larger crowns of those species would be fatal to the existence of the one to be permanently maintained. In the rare case of that species being hardy, of higher stature and a more rapid-grower, and requiring the other species only to form a sort of understory, intermixing of seeds may be allowed, but sowing in separate lines is nevertheless still to be preferred.

CHAPTER V.

PLANTING.

Success in planting depends mainly on:—

(1) A judicious selection of the species to be used;

(2) Choice of the most suitable kind of planting material;

(3) Putting out this material at the right time of the year;

(4) Careful and skilful lifting up, pruning and transport of this material;

(5) The right quantity to put out and its just distribution over the area to be planted up;

(6) The most economical as well as effective mode of preparing the soil and putting down the planting material; and

(7) Adequate care of the plantation until it is established.

SECTION I.

Choice of species.

Besides being adapted to the soil and other local conditions and to fulfil the end sought, as they should in any case be, the species selected should be such as can be planted by some one or more of the numerous methods of planting, and this too at a cost that is not prohibitive. In hard stony soil only such species should be used as concentrate their early vigour mainly on the development of the roots, for it is a well known fact that all planting material, immediately after being put into the ground, has a tendency to exhibit a disproportionate amount of energy in bringing out leaves and twigs at the expense of the reserve food stored therein, on the exhaustion of which the sum total of the parts above ground have acquired such an inordinate predominance over the root apparatus, that this latter becomes quite unequal to meeting the demands made on it and the entire plant then succumbs.

SECTION II.

The various kinds of planting material.

Planting material may be very different according to its origin, its outward form, its size and age, the mode in which it has been raised, and the agency through which it has been obtained.

ORIGIN.—According to its origin planting material for foresters may be either *seedlings*, or individual *rhizomes* or *root-cuttings*, or *suckers*, *cuttings* or *layers*. It is not every forest species that can be propagated by root-cuttings or suckers or layers, still fewer by cuttings, and only the grasses by rhizomes; whereas all woody plants without exception can be raised from seed, which may for all practical purposes be allowed to include the spores of ferns.

In layering, it is best to do so directly in the forest, when there are already some trees on the ground suited for that method of propagation; and, as a rule, the use of layers for forest purposes should be limited to that single case.

Root-cuttings are awkward things to use and should generally be avoided, except the soil and locality be very favourable and it is only a question of covering the ground as quickly as possible, no matter what the class of forest raised is to be.

Rhizomes, provided they are young and not too large, are as suitable as seedlings; otherwise these last are the very best material to use, both because they produce larger, more vigorous, longer lived and sounder individuals, and because, cuttings of certain species excepted, they are invariably more successful. The exception made above in respect of cuttings refers to the few species which, like willows, figs, &c., are readily multiplied by that method of propagation.

OUTWARD FORM.—According to their outward form planting material may be either *rooted* or *without roots*. Seedlings, suckers and root-cuttings must necessarily possess roots, and rhizomes and rhizome-cuttings, although they may have no roots, will have at least what may be called root-producing buds. Cuttings and layers may or may not be rooted, according as they have been previously schooled or not; but the lower nodes of culms possess adventitious roots, which when covered with soil extend themselves and perform all the functions of roots. Transplants of course necessarily comprise all rooted planting material. Transplants may be used with naked roots or have their roots enclosed in a ball of the original undisturbed earth, in which they have grown. Plants from pots or baskets or tiles are special classes of transplants of the latter category.

Then again transplants may be used more or less completely headed down or with the crown more or less entire. Generally only seedlings and rhizomes with developed culms are headed down.

Lastly, the stems composing planting material may be used singly or in bunches or bouquets of two or more together. Only small seedlings and rhizomes and rhizome-cuttings can form a planting bunch.

SIZE AND AGE.—The classification, according to size, of rootless cuttings, has been given in pp. 209-210. Transplants may be divided into three principal size-classes :—(1) *small* plants, those which are not more than a foot high; (2) *middle-sized* plants, those which are between one and three feet high ; and (3) *large* plants, those which are three feet and upwards in height. Large plants which are over eight feet high, may be specially termed *saplings* Yearlings may of course, according to the rapidity of their growth, be small, middle-sized or large plants ; but those yearlings, which have only just come out of the seed, may for convenience sake, be designated *germ plants.*

MODE OF RAISING.—Seedlings may be *self-sown* from the forest or *nursery-raised*, the latter being qualified as *schooled* or *unschooled* according as they have passed or not passed through a period of training in nursery lines. Obviously schooled seedlings may have originally been obtained from the forest. Similarly, suckers and rhizome-cuttings may be spoken of as *schooled*, if they have been through a course of nursery training. Ordinary cuttings and layers may be *direct* or *schooled*, according as they are put down or layered at once in the forest or only after they have been made to strike root in a nursery.

The properties of good transplants have been enumerated and explained in Chapter II, Section I, pp. 134-136, and the age of wood to use for cuttings and layers has been discussed in the same Chapter and Section on pp. 209 and 211. As regards unschooled suckers, the smaller the roots on which they are produced are, the more successful are they likely to be. The character of their crown and stem must approach less or more that given for transplants in general ; but as such suckers have hitherto obtained the whole or the greater part of their nourishment from the parent tree, what may be called their own root-apparatus will necessarily be disproportionately small compared with their crown, and hence the more meagre the latter is and the thicker the stem for the rapid conduction of water, the better. The individual rhizomes of a clump are also dependent on the roots of the clump for their nourishment, although of course not to the same extent as suckers are dependent on their parent tree. Hence the larger and fuller the rhizome is in proportion to the culm it bears, the better the chances

of success. The rhizomes should moreover be free from any unsoundness, and have large and numerous eyes and an abundance of roots.

SOURCE OF SUPPLY.—Planting material may be obtained by purchase, or extracted by one's own agency from the forest, or raised in a nursery under one's own supervision. Those obtained by purchase must be taken after very careful selection, especially if they have not been previously examined in the place itself in which they were raised, and lifted up and transported by one's own agency. Unschooled seedlings from the forest are never so good as nursery-raised transplants, since, in the first place, owing to the generally inferior condition of the soil there, the root-apparatus will be far from compendious and will necessarily suffer heavy mutilation in being taken out; and, in the next place, as such seedlings cannot generally be removed except from those points where their number is in excess of the requirements of the local natural regeneration, they will have generally developed too close together to be strong. Nevertheless if only germ plants are required, those from the forest will be quite as good as those obtained from a nursery.

SECTION III.

Season for planting out.

The best time of the year to plant out is evidently then when all the four following conditions are combined :—

(i) The soil and air should be sufficiently moist and warm ;

(ii) The planting material should possess its maximum recuperative power ;

(iii) It should be in full vegetative activity ; and

(iv) It should, after being put down, have sufficient time to strengthen itself against the very next spell of unfavourable weather—breaks of hot dry weather during the rains, the bright warm October sun, the cold of winter, the drought in April-May &c.

All four conditions are satisfied in every part of India by the few weeks succeeding the setting in of the summer rains ; and for those species which come into activity only then, planting at that time is especially favourable for the simple reason that the plants still contain a large quantity of reserve material and have not yet expended all their pent-up energy of the hot dry months, during which they were reposing. In those districts where no frosts occur and October-November rains, not preceded by a break of hot bright steamy weather, also prevail, the planting season

may extend right up to the last heavy showers that fall in September; but it is always better to plant as early in the summer rains as possible, *i.e.*, as soon as the soil has been saturated and continuous showers have begun to fall. This period will be different in different parts of India. Thus, for instance, to speak in a general manner, it will be the beginning of June for Assam, Bengal, Burma and the Coromandel Coast, the latter half of June for the Malabar Coast, the beginning of July for the interior of the Peninsula, the end of July or beginning of August for Berar, the Central Provinces, Oudh, the North Western Provinces and the western and hill districts of the Punjab; some time late in August for Rajputana and the eastern districts of the Punjab; and so on.

Except where irrigation or some other kind of adequate watering is possible, the entire work of planting, particularly in the case of plants lifted up with naked roots, should be done while rain is actually falling, for under no other circumstance could the necessary immediate intimate connection between the roots and the soil be secured; and if the wet weather should continue for another day or two after the plants have been put into the ground so much the better. As so favourable a combination of natural conditions does not, at least in the greater portion of this country, often occur more than once, it follows that when planting is to be done, a large gang of labourers should be kept ready to come out at a moment's notice and complete the whole, or at least a very large part, of the work on the first good rainy day after the soil has already been saturated.

SECTION IV.

Arrangement of the planted material.

In planting some definite arrangement may be followed or there may be no attempt at order at all. When some kind of order is observed, whatever other rule of disposition is followed, the planting is executed along more or less straight, more or less parallel, more or less equidistant lines.

ARTICLE 1.

REGULAR AND IRREGULAR PLANTING COMPARED.

The following are the principal advantages secured by putting out the planting material in a regular manner:—

(i) *Economy of labour and supervision and facility of execution.* The points at which the material is to be put down are known beforehand and fixed by measurement based on the ruling sylvicultural and economical considerations. There is thus no

time lost in choosing the planting spots, the gang of workmen can be organised and drilled so as to yield the maximum outturn of work, nothing is left to individual caprice, and the men and work can be supervised with the greatest ease.

(ii) *Economy in preparing and carrying the planting material,* for the exact number of transplants, cuttings, &c. required is previously known.

(iii) *Easy appreciation of extent of failure or success.* We have only to count the successes and failures along a sufficient number of lines taken here and there all over the area and obtain thereby the average proportion of success for the entire area or for separate portions of it presenting distinctive characterictics as respects soil, locality, surrounding vegetation and other conditions. Until the plants stand above the grass and weeds, it is extremely difficult to find them all again unless they are arranged according to some definite order, and the task becomes impossible, if there is some self-sown advance growth already on the ground.

(iv) *Facilitation of maintenance operations.*—This follows as a consequence of (iii).

(v) *Rapid growth of the young plants,* since they can nowhere get overcrowded before the entire crop as a whole stands in need of a cleaning (See Part III.)

(vi) *Complete utilisation of pre-existing forest growth.*—A regular arrangement of the planting material allows of its being put down only where, owing to the absence or insufficiency of that growth, it is actually required.

(vii) *Possibility of utilising the area between the lines.*—On the intervals grass may be exploited or field crops raised, the proceeds from the sale of which may be debited against the expenditure on planting, thereby turning to account and making the most of resources that would otherwise be wasted.

(viii) *Facility in mixing species.*—In reference to this the remarks on p. 280 on mixed sowings should be read.

As against these very important advantages, regular planting offers certain disadvantages:—

(i) It produces continuous alleys for the entrance and unchecked passage of winds, which must sweep away the dead fallen leaves and contribute powerfully to the evaporation of soil moisture. This danger can, however, be minimised by running the lines at right angles to the direction of dangerous winds, and planting closer and thereby creating protective curtains along the edge of the area and along roads and other cleared lines.

(ii) Where large game abounds, the animals generally convert the lines into beaten tracks. Thus the soil round the plants gets trodden down into a hard pan, and the plants themselves are knocked over or broken, if they are not also browsed down.

(iii) The planted crop presents a uniformity of aspect and growth which is not favourable to the drawing up of the trees and the formation of clean long boles.

These three drawbacks are of course real and serious; nevertheless the vast superiority of regular over irregular planting is beyond question, and the former should invariably be adopted, save where the area to be filled up by planting is so small that a regular arrangement becomes unnecessary or superfluous, and even difficult to follow, particularly if it comprises numerous little blanks in the midst of an otherwise complete young growth.

ARTICLE 2.

THE MORE COMMON FORMS OF REGULAR PLANTING.

On hilly ground it is obvious that the only extent to which regularity can be secured is by following contour lines or lines nearly coinciding with lines of steepest descent and adopting, as far as possible, an equal spacing in those lines, as in the case of sown patches (*vide* p. 260).

On level ground we have much more latitude, and must hence avoid all figures with unequal angles, which it would moreover be extremely difficult to lay out. Also, for the sake of convenience, figures of more than four sides are never permitted. Accordingly, whatever the variation in smaller details may be, the arrangement of the plants will always be referrible to one of the three following elementary systems:—

(1) The rectangle (Fig. 98).
(2) The square (Fig 99), and
(3) The equilateral triangle (Fig. 100).

The so called quincunx form (Fig. 101), resolves itself into the square system; and the check pattern, of which Fig. 102 gives one form, is simply a peculiar arrangement of rectangles, squares or equilateral triangles. The fifth plant in every apparent quincunx or the interior plants in each check would generally belong to a species that is delicate or narrow-crowned or one which clears its bole with difficulty.

We need therefore consider in detail only the three elementary forms.

§ 1. *Respective number of planting spots in the three elementary forms.*

THE RECTANGULAR PATTERN.—In this pattern the planting spots are the points of intersection of two sets of parallel lines crossing one another at right angles and forming between them equal and similar rectangles. Thus there are two different distances between spot and spot, and, in defining these distances, it is usual to say that the seedlings or other planting material are put down *so many feet apart in lines so many feet apart*, the latter distance being the greater of the two, or the two distances may be connected with the sign of multiplication ×.

To determine the number of planting spots (see Fig. 98), let d_1 and d_2 respectively be these two distances and S_1 and S_2 the two sides of a rectangular piece of ground to be planted up Then $\frac{S_1}{d_1} + 1$ = number of planting spots in each line, and $\frac{S_2}{d} + 1$ = „ „ lines of spots; and the total number of planting spots will be

$$\left(\frac{S_1}{d_1} + 1\right)\left(\frac{S_2}{d_2} + 1\right) = \frac{S_1\,S_2}{d_1\,d_2} + \frac{S_1}{d_1} + \frac{S_2}{d_2} + 1.$$

The three last terms aggregate just one half the number of planting spots along the perimeter of the entire area. When this area is large, they may be neglected; but if they are taken into account, we may generalise the preceding formula for any irregular area thus :—

When planting according to a rectangular pattern, divide the total area of the ground in square feet by the product of the two planting distances and half the perimeter in feet by the shorter of these distances; the sum of the two quotients will very nearly give the total number of planting spots to be prepared.

THE SQUARE PATTERN.—Here $d_1 = d_2 = d$ say. Hence the number of planting spots, according to the formula given above,

$$= \frac{S_1\,S_2}{d^2} + \frac{S_1 + S_2}{d} + 1;$$

and we have the following general rule :—

When planting in squares, divide the total area of the ground in square feet by the square of the planting distance, and half the perimeter in feet by that distance; the sum of the two quotients will very nearly give the total number of planting spots to be prepared.

In operating over large areas, the value of the two last terms obviously becomes insignificant.

THE EQUILATERAL TRIANGULAR PATTERN.—Referring to Fig. 100, we see that the distance between the consecutive planting spots along AD and lines parallel to AD is equal to the side of the equilateral triangle, whereas the distance between those lines (*ab*) is equal to the height of the triangle. If d = the former distance, then d sin60° = 0·87 × d = the other. As before let AD = S_1 and AB = S_2.

It is obvious that there will be two cases according as the fractional portion of $\frac{S_1}{d}$ is less than, or is at least equal to, one-half, or, which comes to the same thing and is more convenient for the investigation which follows, according as $\frac{S_1}{d}$ is a whole number or a whole number *plus* one-half.

Suppose first that $\frac{S_1}{d}$ is a whole number, then the number of planting spots in the lines will be alternately $\frac{S_1}{d}$ and $\frac{S_1}{d} + 1$, and the number of lines will be $\frac{S_2}{0{\cdot}87 \times d} + 1$. If this last number is even, half the number of lines will contain $\frac{S_1}{d}$ planting spots and the other half $\frac{S_1}{d} + 1$ spots, the total number thus being

$$\frac{1}{2}\left(\frac{S_2}{0{\cdot}87 \times} + 1\right)\left\{\frac{S_1}{d} + \left(\frac{S_1}{d} + 1\right)\right\}$$

$$= \frac{S_1 S_2}{0{\cdot}87 \times d^2} + \frac{S_1}{d} + \frac{S_2}{1{\cdot}73 \times d} + \frac{1}{2} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{(i)}$$

If that number is odd, then, according as the odd line contains $\frac{S_1}{d}$ or $\frac{S_1}{d} + 1$ planting spots, the total number of planting spots will be

$$\frac{1}{2}\,\frac{S_2}{0{\cdot}87 \times d}\left(\frac{2\,S_1}{d} + 1\right) + \frac{S_1}{d} = \frac{S_1\ S_2}{0{\cdot}87 \times d_2} + \frac{S_1}{d} + \frac{S_2}{1{\cdot}73 \times d} \quad \ldots \quad \text{(ii)}$$

or

$$\frac{1}{2}\,\frac{S_2}{0{\cdot}87 \times d}\left(\frac{2\,S_1}{d} + 1\right) + \left(\frac{S_1}{d} + 1\right) = \frac{S_1\ S_2}{0{\cdot}87 \times d_2} + \frac{S_1}{d} + \frac{S_2}{1{\cdot}73 \times d} + 1 \quad \ldots \quad \text{(iii)}$$

Next suppose that $\frac{S_1}{d}$ is equal to a whole number *plus* one-half, then the number of planting spots in each line will be the same and will be equal to $\frac{S_1}{d}$, and the total number will be

$$\frac{S_1}{d}\left(\frac{S_2}{0{\cdot}87 \times d} + 1\right) = \frac{S_1\ S_2}{0{\cdot}87 \times d_2} + \frac{S_1}{d} \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{(iv)}$$

As before, all but the first term in the four preceding equations may be dropped, when the area operated in is large, a small percentage for contingencies being, however, allowed for; and if those equations are generalised into a single universal rule sufficiently accurate for all practical purposes, we may say that—

When planting on the equilateral triangular pattern, in order to obtain the number of planting spots, we divide the area expressed in square feet by 0·87 times the square of the planting distance and increase the quotient by the quotient of half the perimeter in feet divided by that distance.

GENERAL.—In elementary works on sylviculture it is usual to give a table showing at a glance the number of planting spots that go to the acre for the most common planting distances in the three elementary forms of arrangement. Such a table saves much tedious calculation. We, therefore, subjoin the following, the figures in which have however been worked out by means of the three rules given above in Italics, and not, as is usually done, by neglecting all but the first term in each of the six preceding formulæ. Besides that the first term alone always gives less than the actual number of planting spots, an appreciable quantity of planting material has to be rejected by the time it reaches the area to be stocked, or is lost in transit or during the planting. The figures in the subjoined table are practically exact for one acre, but slightly exaggerate the number of planting spots for a larger area

Planting distance in the lines. Feet.	Number of planting spots in an acre on the														
	SQUARE PATTERN.	EQUILATERAL TRIANGULAR PATTERN.	RECTANGULAR PATTERN, the distance in feet from line to line being												
			3	3½	4	5	6	7	8	9	10	12	15	20	30
1	...	...	14,940	12,870	11,310	9,140	7,680	...	...	...	...	..	...	...	...
1½	...	...	9,960	8,580	7,540	6,090	5,120	4,430	3,910	...	...	...	...	...	...
2	11,100	12,800	7,470	6,430	5,660	4,570	3,840	3,320	2,930	2,630	...	...	...	...	...
2½	7,140	8,180	5,980	5,150	4,520	3,650	3,070	2,660	2,340	2,100	1,910	...	...	...	...
3	4,980	5,700	...	4,290	3,770	3,040	2,560	2,210	1,960	1,750	1,590	1,350	...	...	...
3½	3,680	4,210	...	...	3,230	2,610	2,190	1,900	1,680	1,500	1,370	1,160	950	...	...
4	2,830	3,230	...	...	...	2,290	1,920	1,660	1,470	1,320	1,190	1,010	830	...	...
5	1,830	2,090	...	...	...	...	1,540	1,330	1,170	1,050	960	810	670	520	..
6	1,280	1,460	...	...	...	...	...	1,110	980	940	800	680	550	430	310
7	950	1,080	...	...	...	...	...	...	840	750	680	580	480	370	270
8	730	840	...	...	...	...	...	...	...	660	600	510	410	320	230
9	580	670	..	..	...	...	...	...	...	...	530	450	370	290	210
10	480	540	...	...	...	...	...	...	...	...	...	410	330	260	190
12	340	380	...	...	...	...	...	...	...	..	...	...	280	220	160
15	220	250	...	...	...	...	...	...	...	...	...	..	...	170	130

§ 2. *The three elementary forms of regular planting compared.*

For the same spacing between the planting spots we can grow on the equilateral triangular plan very nearly 1·155 times more plants than on the square system. In the equilateral triangles every plant is surrounded by six others standing at an equal distance from it, and from one another; whereas in the squares each plant is immediately surrounded by only 4 others, and these are further away from one another than it is from them. Hence more symmetrical growth in the equilateral triangle arrangement. The result both of the nearer spacing and the more symmetrical development is earlier and more complete formation of the leaf-canopy, whereby the fertility of the soil is more effectively secured and maintained, and the trees get better drawn up and produce cleaner and longer boles. On this account the production is larger and of better quality. Lastly, the earlier and more complete formation of the leaf-canopy precipitates the acute stage of the struggle for existence and necessitates an earlier removal of a part of the crop, so that the plantation becomes productive at an earlier age. No doubt, by planting closer, the intervention of the woodcutter would be called for just as early in a plantation formed on the square pattern, but this will be at the expense of each individual plant, which will obviously have insufficient elbow room and will thus be kept back and will have attained smaller dimensions when the cutting will be required to correct the overcrowding. The equilateral triangular arrangement has, however, also its drawbacks; it is the most difficult of the three to lay out (see page 298), and it is impracticable or entirely superfluous in the midst of an existing useful forest growth. In this last case, the square system also results in a great waste of labour and planting material. And, indeed, it is mainly when land perfectly bare of trees and shrubs has to be covered as quickly as possible with tree growth, that the square, and particularly the equilateral triangle, arrangement asserts its superiority over the rectangular method.

In such areas this last pattern, especially if the disparity between the distance from plant to plant in the lines and that from line to line is very marked, necessarily results in an elliptical development of the crown and the roots and, therefore, of the bole itself, for the trees have more growing room outwards than in the lines themselves. An elliptic shape detracts from the value of the bole for sawing and other purposes, as the consequent irregular thickness of the individual concentric rings of wood predisposes the timber

to unequal shrinkage and expansion, and, therefore, to warping, twisting, and even splitting. This inherent defect of the rectangular method can of course be minimised by putting the lines close together, but in that case the system would approximate to the square arrangement and would cease to have a distinctive character. Nevertheless the rectangular system has its place in bare open areas, when the conditions of vegetation are so unfavourable that a large proportion of casualties is expected; close planting in the lines is one way of providing against such casualties, and if these occur uniformly throughout the crop, the survivors must ultimately present the aspect of the square pattern.

But it is when the area to be planted up already contains an appreciable and evenly distributed amount of utilisable and useful growth that the rectangular arrangement possesses an undoubted superiority over the other two systems, as it makes the most of this previous growth by giving it plenty of standing and growing room between the lines, and allowing for whatever comes in the way of the lines being at once assimilated with the mass of new plants put down. For this reason also the rectangular system should generally be followed in planting under a high nurse crop that is capable of producing its own seedlings or is to be cut over for coppice.

The rectangular arrangement should be adopted also in the following cases:—

(1) When an agricultural crop is to be raised between the lines of seedlings.

(2) Where grass is a valuable commodity and its production cannot be at once or altogether stopped.

(3) In pasture land where the presence of trees is required to foster and improve the production of grass.

(4) When a nurse crop is put down, to be shortly followed by the species whose propagation is desired.

(5) When the growth of weeds is so tall and dense, that the plants put down cannot overtop it until they have attained a certain height and, therefore, a certain spread of crown. What is then required is only to prevent the weeds from invading the lines, and this end can be secured only by putting down the plants close together in the lines so that they may afford each other mutual protection, that is to say, by following a decidedly rectangular arrangement. If the square system were adopted, the planting would have to be so close, both for convenience of supervision and for the safety of the plants, that it would require the cutting away of

nearly the entire mass of weeds, not only once in order to put down the plants, but for several years running afterwards until the plants became strong enough to be able to resist suppression. Such an operation would be as undesirable as it would be extravagantly costly. It must be remembered that tall weeds are very useful in affording shelter to young plants, and their usefulness in this respect should be turned to the best account.

SECTION V.

Closeness of planting.

The distance that should intervene between two consecutive planting spots will be determined by the following considerations:—

(i) *The nature of the species used.* The more delicate or the more slow-growing they are, the closer together must the plants be put. Sucker-producing species may be planted further apart, and so on.

(ii) *The time in which it is desired to produce a leaf-canopy.* In purely pasture lands, there must of course be no leaf-canopy and the plants must stand far apart. In a poor dry soil, on unstable slopes, and so on, the sooner the leaf-canopy is formed, the better.

(iii) *The age, size and vigour of the planting material.* The younger or smaller or weaker this material, the closer must it be planted.

(iv) *The kind of planting material used.* Cuttings without roots will generally be put down closer than rooted plants; root-suckers than seedlings of the same size; rooted plants with covered roots than plants with naked roots; and so on.

(v) *The climate and locality.* The severer the climate, the steeper the gradient, the more windy or frosty the locality, and so on, the closer must we plant.

(vi) *The degree of suitability of the soil for the species used.* The less suitable the soil, the closer together must the plants be put down.

(vii) *The nature of the surrounding vegetation.* The planting must be closer in perfectly bare treeless or shrubless land than in the midst of useful woody growth, especially if this consists of seedlings or seedling-shoots of valuable species, or of trees capable of producing a new generation of seedlings. If the surrounding vegetation is injurious and must be suppressed quickly, the planting should be close. And so on.

(viii) *The object of the plantation.* If protection against landslips, erosion, avalanches, hot winds, &c. is required, we must plant close. If the early production of large poles is desired, then the plants should be put down further apart than if lofty trees with long straight clean boles were to be grown. In pasture lands we want only a few trees, solely to afford shelter and to maintain a good crop of grass. In simply introducing a species for the first time or merely increasing its proportion, the planting will be sparse. And so on.

(ix) *The exposed position of the area to be planted up.* Thus the planting will be closer on the edge of a forest or along a road than in the interior.

(x) *The state of the demand.* If small wood sells readily, we would obviously plant closer than if it had no value at all. If grass were valuable, there need be no hurry in suppressing it by close planting. And so on.

(xi) *The number of plants put down together at each point.* The object of putting down more than one individual at each planting spot is to provide for one plant at least succeeding at each point. The chances of complete failure being thus minimised, we may safely plant less close than if the plants were used singly.

(xii) *The ease and readiness with which failures may be repaired.* The more difficult it is to undertake or effect repairs, the closer must we plant.

In finally fixing upon the distance or distances at which single plants should be put down, it should be remembered that it is as great a fault to put down too many as too few individuals; for when the plants stand too close together, they remain underfed and, unless thinned out early, become so weakened that the annual sum of production falls below what the soil is capable of yielding, and, in any case, since the number of plants increases inversely as the square of the distance between them, there is an unnecessary waste of material and labour, and, therefore, also of money.

Under any circumstances the distance from planting spot to planting spot in the square or equilateral triangular pattern ought never to be less than 2 feet or more than 10 feet, the most advantageous being generally from 4 to 6 feet; while in the rectangular arrangement, the distance between the lines would usually vary from 3 to 15 feet, from 6 to 12 feet being

oftenest adopted, and that between the planting spots would range from one-sixth to nine-tenths of the former distance, from one-third to one-half being the most common ratio. Exceptionally, in the case of fodder preserves or when there is an abundance of useful growth already on the ground, the distance between the lines may be 20 to 30 feet, with 5 and 10 feet respectively as the minima and maxima distances between the planting spots.

SECTION VI.

Marking out the planting spots.

On level ground. If the area is large, it should be divided into compartments of manageable size, each compartment forming a unit of work. It is always advisable to have the compartments in the form of squares or rectangles, the sides of which measure a chain or some multiple of a chain, or better still some convenient multiple of the planting distances. By this means not only does the actual marking out, but subsequently also the planting becomes systematised, so that it is more easily, more economically and more efficiently executed and supervised, and its progress from day to day and hour to hour is exactly appreciated and regulated without any trouble. If the perimeter of the area is of an irregular shape, in addition to the squares or rectangles, as the case may be, in the interior, there will be triangles and trapéziums along the outside; but these figures are themselves geometrical shapes and will in any case rarely be so numerous, and never so large, as to disturb the mathematical precision of the lines of work.

In each compartment the planting spots may be expeditiously and sufficiently accurately marked out in the following manner:—

Along two opposite sides peg out the ends of the planting lines. Then draw a chain in a straight line between two opposite pegs, marking each planting spot with a single blow from a pick or by means of a stake driven into the ground. Chains of a special length should be used and the planting distances should be indicated on it by means of small brass labels.

The preceding plan requires workmen trained to drag the chain in a perfectly straight line between two given points. It is, however, difficult to teach the native of India, of the classes which supply our coolies and forest guards, the art or the

necessity of chaining straight. A simpler and more certain plan for all classes of workmen will be as follows:—

Instead of using chains that are dragged about, take strong lines of some material not affected by wet and of the same length as the side of the compartment, which should on that account not be large. To the end of each line a strong wooden peg should be securely attached, and knots of coloured wool should be tacked on along the line at the required intervals. In the square system of arrangement only a single line per workman is needed; this should first be stretched along two opposite sides of the compartment in order to mark thereon the planting distances, and then at right angles to them successively between two opposite points marked out, until the entire compartment is completed. For a rectangular arrangement we want two lines to indicate separately the two different distances, or one and the same line may be used, the two different intervals being marked thereon with wool of two different colours. For laying out equilateral triangles three lines are required, one to indicate the height of the triangle (the side × 0·87) and the other two, giving the length of the side of the triangle, to mark out alternately *(a)* the rows the first planting spot of which is on the edge of the compartment and *(b)* the rows the first planting spot of which is half the length of the side away from the edge of the compartment. Obviously the last two lines can be replaced by a single one bearing knots of two different colours alternately, the interval between two successive knots of the two different colours being equal to half the side of the triangle.

In areas of limited extent equilateral triangles may be laid out with the help of two straight bamboos or poles, each equal in length to the side of the given triangle. One of the poles is first laid on the ground in the middle of the area and pegs driven in at its extremities. Then both poles should be so placed on one side of this line as to form with it an equilateral triangle, the apex of which should be staked. Similarly the apex of the equilateral triangle on the other side should be marked. We thus obtain a nucleus of two triangles, by producing the sides of which either way and measuring off new distances, we complete the required network of equilateral trinagles.

The laying out of planting spots according to modifications of the square and rectangular systems, as for instance the check pattern (Fig. 102), &c., will obviously be effected on the same principles as those systems themselves.

ON BROKEN OR HILLY GROUND. Here the formation of square or rectangular compartments is of course out of the question and work will obviously be done most conveniently by taking as the working unit either one side of a drainage basin or the whole of a small basin or the area between two small drainage lines. Moreover the three elementary forms of arrangement of the planting spots (with their modifications), now rendered impossible by the slope of the ground, must be given up for planting spots following contour lines and equally spaced only in those lines, just like sown patches and hollows on similar ground; and if the hill side is very steep, the lines of planting spots still resembling sown patches, will very nearly coincide with lines of steepest descent.

SECTION VII.

Lifting up of transplants.

NURSERY PLANTS. The lifting up of seedlings to be planted out in nursery lines has been described on pp. 200-201. The procedure here is just the same. But, whereas in the case of those seedlings, besides that the distance of transport is almost *nil*, they can be put back into the ground almost as soon as they have been taken up, and in putting them down and looking after them until they have fully struck again, the nurseryman commands every condition necessary for success; in putting out into the forest, on the other hand, the distance of transport may range from a few yards to several hundreds of miles, the plants, after arrival at destination, may have to be kept for several days before they are used, and the suitability of the soil and locality and the propitiousness of the weather and other attendant conditions are factors, over which the forester can exercise little or no control. Hence in lifting up transplants, especially if they are large seedlings or are suckers, rooted cuttings and layers, all of which possess less tenacity than seedlings, much greater care must be observed in preserving the roots and in causing as little injury as possible to the plants.

To that end large transplants should be very carefully dug out with a sufficiently large ball of earth, which should be kept from breaking by wrapping it round tightly with matting or coarse cheap canvass. If the plants are very large and their roots have spread out a considerable distance laterally, the labour of a last transplanting may be saved by the following plan of

lifting up. Toward the close of the season of vegetation immediately preceding that in which the plants are to be put out, or at the beginning of spring for those species which come out into leaf then, a circular trench, of a depth equal to the depth of roots required for transplanting, should be dug round each plant, leaving a sufficiently large cylinder of earth surrounding it. In excavating the trench, all the roots extending beyond the cylinder of earth should be carefully pruned off. This cylinder should now be swathed round with matting or canvass, and the trench filled up with some strong manures, but so treated as to be avoided by white ants. The object of the manure is to provoke a vigorous development of rootlets and root-hairs just inside the cylinder of soil, none of which roots will be able to penetrate beyond the manure. At the beginning of the next ensuing summer rains the plants can be taken out with no worse injury than the loss of their deeper roots. When the ball of earth is very large and heavy, boards should be placed under it and pulleys should be used to lift the plants out of the ground.

SPONTANEOUS PLANTS FROM THE FOREST. Self-sown seedlings out in the forest, having come up in a hard, not usually fertile soil, generally possess a long thin tap-root with but few and weak lateral roots. It is not easy to lift up such seedlings, especially from the hard soil in which they grow, and hence only such should be used as are small enough to be taken up with a khurpa, trowel, spade or hoe.

Unschooled suckers and rhizome divisions from the forest are also deficient in root development; but when they have to be used, the former should be such as have come up on small parent roots, while the latter should be taken from clumps the culms of which are not too closely packed together. The implements to work with would be picks, grubbing and other axes and strong hoes.

SECTION VIII.

Pruning of the transplants before transport.

The object of pruning transplants before they leave the nursery or other place where they have grown, and not postponing the operation until they reach the forest and are about to be put down, is to diminish their size and weight and thus facilitate and cheapen their packing and transport.

ARTICLE 1.

When and to what extent to prune.

In a general manner it may be said that the less a plant is pruned the better, since pruning is synonymous with the reduction of its absorbing and assimilating organs. Hence pruning should be strictly confined to cases of necessity or of obvious advantage, and limited to the removal of only those parts which the plants, in their condition at the time of being packed up, may lose without suffering any serious injury.

The answer to the question heading this Article will depend, according to circumstances, on one or more of the following considerations.

(i) *The general contour and habit of the transplant.* If the transplant is healthy and vigorous, it has a shape and general aspect peculiar to itself, which we may call its *normal* form.* Whenever a plant departs from that form, it is advantageous, and indeed frequently necessary, to prune it, so as to enable it to assume that form. For instance, if the crown is irregularly shaped, possessing too much vigour on one side or at certain points, it may be benefitted by the suppression or reduction of the abnormally developed parts; and when the crown has been pruned, the roots will also require being pruned in order to maintain the necessary equilibrium between the absorbing and assimilating organs. On the other hand, it may be the roots that show an abnormal mode of development, in which case first the roots and then the crown must be pruned. Then again the plant may be thin and lanky, with a disproportionately small crown, a defect that would render its establishment impossible or at the best slow and arduous, owing to the long and narrow channel for the passage of the sap from the roots to the attenuated crown. As a rule, such plants would be altogether rejected; but if they *can* stand the pruning and there is an insufficiency of more vigorous plants, they should be headed down. In the next place, if the stem is crooked, it may be straightened by being cut down to the level of a healthy and strong branch or bud.

(ii) *Extent to which the roots have been damaged in being lifted up.* If the injury is not so severe as to render the re-establishment of the plant uncertain or doubtful, the jagged and badly bruised portions of the roots should be taken off, necessitating a proportionate reduction of the crown.

* See page 14, last paragraph.

(iii) *The size of the plant.* A small seedling can generally be lifted up without suffering any appreciable injury, and the extent of the injury will ordinarily be in proportion to the size of the plant. Moreover, the larger a plant is, the longer will be the distance up which the sap will have to travel from the roots, and the more will the crown be exposed to be damaged by wind or other atmospheric influences. Hence the larger a plant is, the more pruning will it generally require; and not only this, but the better will it be able to stand being pruned.

(iv) *The species to which the plant belongs.* Different species can obviously bear different degrees of pruning. Thus conifers can bear pruning least of all; they not only, as a rule, possess few buds, but these are situated mainly at the extremities of the stem and branches, and they moreover secrete resin, which clogs the cut surfaces of the roots and renders them incapable of absorbing moisture from the soil. *Pinus longifolia* and deodar are striking exceptions to the general rule, but even they cannot stand being pruned to the same extent as most of the broad-leaved species. In the case of conifers the pruning should ordinarily be limited to the removal of a hopelessly damaged leader, to the foreshortening or entire removal of only the lowest branches, and to the trimming off of all badly bruised or broken portions of the roots.

As regards the broad-leaved species, there are many, which, like teak, sal, *Terminalia tomentosa*, &c., producing as they do numerous vigorous collum-buds, can bear being completely headed down, the vitality of the roots and the reserve matter left in them enabling the little stumps to throw up strong shoots, that in the end, without loss of time, attain the same development as the original stem and crown would, under the best circumstances, have done. Some from among these species, like teak, sal and others, although they can stand almost any extent of pruning of the overground organs, suffer very appreciably if deprived of even a small part of the younger portions of their root-apparatus. Such species are generally either those which, like teak, develop rapidly a very large and active transpiring surface, or those which, like sal and sissu, bring out their leaves at the beginning of the hot dry season, and must, on that account, have their principal roots inside the permanently moist and, therefore, deeper layers of the soil. A third class of broad-leaved species, like the various kinds of

figs, mulberry, willows, &c., being able to grow up from cuttings, do not mind the severest pruning both of the crown and roots. And so on.

Bamboos may be cut down to the last or last but two knots.

(v) *The soil and locality.* According to the humidity and fertility of the soil in which the planting is to take place, a transplant may be pruned more or less severely. In a moist rich soil absorption can go on rapidly through a relatively small number of roots and growth is vigorous and soon enables the mutilated roots to recover and reform themselves completely. Hence, when planting in such soils, the roots may be pruned comparatively severely, both with reference to their own original abundance and condition and to the size of the stem and crown; whereas in dry or poor soils the pruning of the roots should be limited to the removal of the damaged, useless portions, while the crown, on the other hand, may be freely reduced in comparison with the roots, in order to make sure that the transpiring surface shall not be in excess of the absorbing surface. Similarly, in unfavourable situations we would act just as we would do in the case of bad soils, and in favourable situations as in the case of good soils.

(v) *The object to be fulfilled by the transplants.* Suppose, for instance, that the transplants are to be put down under a standing copse, in order either to keep up a sufficient supply of seedling shoots, or to introduce or increase the proportion of a certain species; in that case, rapid growth is not only not possible under the more or less dense cover of the copse, but is indeed not required at all, what is wanted being simply that the transplants shall do little more than merely live until they are cut back with the coppice, to become thenceforward a part of new regrowth itself. Hence, if other circumstances do not forbid it, the transplant may be pruned severely both in respect of its root-apparatus and its crown. On the other hand, if the transplant is to be put out under high forest, it ought, as a rule, to be pruned as little as possible. And so on.

ARTICLE 2.

How to prune.

Whenever we prune, a clean section must be made—for plant-parts above ground, in order to prevent dew and rain lodging on the cut surface and hastening decomposition; for the portions under ground, in order to allow water to enter the roots easily and pass

rapidly upwards, a jagged or spongy surface diminishing or totally destroying the moisture-conducting power of the wood-fibres. This is also a reason for making an oblique section, in order to allow water to flow off at once in the case of the parts above ground, and to produce as large an absorbing surface in the case of the roots. Hence only very sharp tools should be used, such as the ordinary pruning knife, a light hatchet, or a pair of garden shears (Fig. 103), &c.

The plant-parts to be pruned may have either to be merely shortened or to be cut off flush with the organ that bears them. Branches to be shortened must be pruned off just above a vigorous bud or daughter branch. Similarly, if the leading shoot, for any reason, has to be removed. In the case of conifers, the section will of course always be just above a branch or vertical of branches, according to the habit of the species. The training of one of the branches of the topmost verticel as the future leader must take place after the plants have been put out. In the case of bamboos, when the stems are large, it is always advisable to cut off at least half the entire length, and often even more, leaving only 4 or 5 knots at the outside. Injured roots should be trimmed down to the required length, or, if already short enough, they should be cut off just above the damaged portion. Shears ought to used only for small plant-parts, not exceeding say a third of an inch in diameter; the pruning knife answers for larger parts, up to half an inch or more, but it has this disadvantage that its use necessitates a certain amount of handling, that is dangerous for roots. Hence roots should generally be pruned only with shears or with a hatchet. This last must be used on a block of wood. It is the only tool with which thick parts can be cut off, especially when plants of some size have to be headed down.

SECTION IX.

Packing and export of planting material.

The chief danger to which all planting material, before being used, is exposed is loss of moisture, which leaves the green parts by the process of transpiration and the remaining parts in consequence both of direct evaporation and the suction power exerted by the transpiring organs. In parting with their moisture, green herbaceous parts not only become flaccid and shrivel up, but their tissues become disorganised and, when a certain stage of disorga-

nisation has been reached, begin to undergo decomposition; while the root-hairs, if there are any, are killed outright by a few minutes free exposure. As regards the woody portions, they suffer a diminution of their peculiar absorptive and conducting powers in respect of moisture, and, as this diminution progresses, a point is ultimately reached at which the loss becomes permanent. Under the most favourable circumstances the vitality of the plants is diminished and their recovery rendered uncertain. Hence the necessity of special care in packing up and transporting the planting material and in keeping it before it can be used. *Cœteris paribus*, plants with naked roots will require most care, particularly such as exceed the mean dimensions of the middle-size class or possess few root-fibres.

ARTICLE 1.

Packing and transport of seedlings.

Whatever the method of packing or carriage, or the distance of transport, the plants should be packed with as little delay as possible after being lifted up, and they should be freely watered as soon as they have been packed up; while during the transport they should be protected against evaporation. Not only the roots and stem, but also the crown in order to check transpiration, should be shaded from the sun.

The longer the transport, the greater will be the chances of injury and the more imperative will it be to so pack the plants as to reduce to a minimum their liability to be damaged. Hence the method of packing, and sometimes even of carriage, will be different according to the distance of transport.

§ 1. *Transport over short distances.*

The directions which follow are intended generally to apply to distances not exceeding a day's journey by any method of conveyance except railways.

Seedlings taken up with a ball of earth. The main precaution required is to prevent the ball of soil breaking away from the roots. Hence they should be packed up as close together as possible, and any small intervals left between the individual balls of earth should be filled up with good light soil. If the plants are to be carried out in baskets, the bottom and sides of the baskets should be lined with such soil, so as to close all interstices. The baskets used should be as rigid as possible,

otherwise they will be continually changing shape under the ever changing pressure inevitable during transport and thus produce rupture of the balls of earth, if not of the roots themselves. Special packing cases, with one side hinged so as to fall back and facilitate the removal of the plants are much better than baskets. These cases may be converted into handbarrows carried by two coolies. When the nature of the ground permits, wheelbarrows or hand-carts, with a similarly hinged side, would be used with a great saving of labour, time and money; and if the country is suited for bullock waggons, these would be the most economical means of conveyance for distances exceeding 300 or 400 yards. The waggons should be deep and contain one or more sliding trays, so that several tiers of small plants may be carried one over the other. If the journey is to extend over several hours of day-light, it is advisable, although not absolutely necessary, to shade the plants with a piece of dark-coloured cloth or with a light cover made of tough leaves, such as those of *Bauhinia Vahlii*, teak, palms, &c.

SEEDLINGS WITH NAKED ROOTS. If the distance is very short and the weather wet, it will often suffice to lay the plants more or less loosely in long baskets or wheel or hand barrows lined with moss or soft green grass or leaves and twigs, which should also be spread over the roots and lower part of the stem. Before putting the plants into the baskets it is often advisable, when the weather is uncertain, to dip the roots in water thickened with fine clay or cattle droppings, which forms a thin protective coating over them. For longer carriage it is a good plan to pack them horizontally in rectangular bamboo baskets with removeable covers, the lining of green soft stuff not being omitted. If the entire length of the plants does not exceed 2 feet, and men able to carry banghies are available, the plants may be packed upright in light iron buckets, which should then be filled up with with water or, better still, with liquid mud. For long carriage, waggons with high sides, if their employment is practicable, are most to be recommended; in them the plants will be laid horizontally on the bottom and on the trays, and pressed as tight as they can be packed together without being injured.

The amount of care and precautions to take will of course always depend on the condition and general characteristics of the weather and particularly on the nature of the species. Species developing rhizomes or capable of growing from cuttings will obviously require least care.

According to the size of the plants and whether their roots have been dipped or not in liquid mud or manure, an ordinary man will carry from 300 to 1,500, a wheelbarrow will take at least twice as many, and a 2-bullock waggon from 5,000 to 50,000 on a kacha road and very nearly double that number on a macadamised road. Hand-barrows should be used chiefly for plants, the length of which, inclusive of the roots, exceeds 3 feet.

§ 2. *Transport over long distances.*

Such transport includes journeys lasting over a day, and carriage by rail or boat, for which we want a maximum of weight with a minimum bulk.

For some time to come we shall never have occasion in India to carry any large number of transplants farther than a 2 days' journey on coolies or in bullock waggons. Indeed, with any other mode of transport than by rail or boat, it will always pay to have separate nurseries for distances exceeding that just mentioned. Nor has Indian forestry or the country yet developed so far as to enable us to employ railway or water-carriage for any thing more than very small consignments of plants. Nevertheless this Manual would be incomplete without some description of the modes of packing and carriage suitable for long transport.

SEEDLINGS WITH A BALL OF EARTH. For journeys extending over several weeks, during which the plants can receive little or no attention, Wardian cases (Fig. 104) should be used. It is obvious that the use of Wardian cases should be limited to the carriage of plants that are rare or quite new in the country into which they are being imported.

For ordinary journeys by road or rail or river, which journeys seldom last more than a week, a less expensive mode of packing is required, since the plants can either be attended to almost every day, or need not be watered at all until they reach their destination. The packing should be effected in wooden cases after the same manner as for a day's journey, except that the balls of earth should, in view of the longer transport and the severer jolting they will be subjected to, be packed closer together and with greater care, and the further precaution may be taken of covering the soil in the cases with moss or pounded charcoal. Stiff covers made of split bamboo are always to be recommended.

Not unfrequently the ball of earth is kept round the roots in order only to protect these, not to be put down with them. In

that case the earth should be compressed tight, in a compact mass, over the roots and the plants should be wedged in close together amongst one another, the intervening spaces being of course filled up with good soil. The plants can obviously be lifted up with more or less naked roots, the ball of earth being put on only afterwards.

SEEDLINGS WITH NAKED ROOTS. The plants may be packed up (A) in baskets or (B) tied together in bundles. Packed in either way, they remain fresh and moist, without being watered, for from 4 to 10 days.

A. The baskets used should be round, with somewhat sloping sides, so that they are broadest at the top. The first thing to do is to line the inside with moss or fresh green grass and leaves, and then with soft moist soil. Next, the plants should be arranged all round the sides, so that they lie obliquely, with all their roots meeting in a mass in the middle; and finally the whole mass of roots, including an inch or two of the stems, should be covered over with soil similar to that in the lining. This soil should be well pressed down so as to leave no air spaces inside. If the plants are to stand a long hot or dry journey, they should be protected with a similar, but flatter basket sewn or tied on to the lower basket. Such covers will not only protect the plants from strong light or drought and external injuries, but permit of just enough transpiration and assimilation to keep them healthy and give free ventilation. Before the covers are put on, moss and green leafy twigs may be piled up over the plants. This method of packing is especially suited to delicate plants, especially yearlings and others containing a comparatively small proportion of well-lignified parts. From 10,000 to 25,000 yearlings may be packed up thus in each basket.

B. When the plants are tied up in bundles, they may according to their size, lie with all their crowns at one end and their roots at the other, or half the plants may be laid one way and half the other way. These two styles of bundles may be turned respectively the *single-headed* and *double-headed* bundles.

We will first describe the *double-headed* bundle, as it is specially suited for small and the lowest catagory of middle-sized plants, which are more often transported over long distances than those of a larger size. It is made up in the following manner:—Two to four or five bands of some long flexible stems, split or entire, such as those of bamboos, *Bauhinia Vahlii* and most other

climbers, willows, *Vitex Negundo*, *Nyctanthes Arbor-tristis*, or of fibrous bark, such as that of the Grewias, *Helicteres Isora*, *Hardwickia binata*, &c., or of twisted grass, such as Bhabar, Munj, &c., should be laid parallel to another on the ground. The number of bands will of course depend on the length of the plants to be packed together. Immediately over these bands should be evenly spread twigs of species with tough, not easily detached leaves, or, better still, large firm leaves, like those of *Bauhinia Vahlii*, *Butea frondosa*, teak, palms, &c. When twigs or fronds are used, the thick end of the stalks should project beyond the two outside bands; and when detached leaves are used, they should be spread thickly over a number of thin rods or switches laid parallel to one another and at right angles to the bands. Along the middle wet moss or soft green grass and leaves should be spread. Over all this the plants to be transported should then be so arranged that the roots lie in the middle over the moss or green grass and leaves between the crown on either side, and the crowns themselves should just stop short of the end of the twigs or rods below. When a sufficient number of plants have been thus arranged, the bands should be tightly drawn over the whole and tied up, forming a more or less cylindrical bundle. In these bundles the roots are completely withdrawn from the influence of the outside air, and the crowns, being pressed together and covered at the end of the bundles by the projecting extremities of the twigs and rods, transpire as little as possible and are protected from physical injuries. According to the size of the plants the number in each bundle will range in round numbers from 300 to 1,000.

The larger category of middle-sized plants and those of the higher classes are generally both too long and too strongly developed in the stem and roots to be packed up in any but single-headed bundles. These are formed and tied up in the same way as double-headed bundles, except that all the foliage is on one side, and the roots, and therefore the packing of moss and other soft green stuff, on the other. It is evident that the shape of such bundles will be conical, the roots forming the apex, which should be well closed. It is equally evident that the plants, especially the root portion, are not so well protected here as in double-headed bundles, and that on this account plants above 2½ feet in length exclusive of the roots ought to be transported over long distances only in very exceptional cases. A single bundle will contain from 50 to 150 middle-sized plants and from 15 to 50 large plants.

It is obvious that yearlings, and other small plants of herbaceous and, therefore, tender constitution, are hardly adapted for being packed up in bundles of either kind.

ARTICLE 2.

PACKING AND TRANSPORT OF SUCKERS.

With the root portion surrounded with soil, suckers that have not developed on large roots and are themselves of moderate size, may be packed and transported in the same manner as seedlings, which they will practically resemble in every respect if they have been schooled. Indeed schooled suckers, provided they are still within the category of the lower class of middle-sized plants, may even be packed up in double-headed bundles. Unschooled suckers, being still to a great extent dependent on the parent tree for their sustenance, possess, as a rule, few rootlets and root fibres of their own, and would on that account be best carried out in soil, or in a bucket of water or thin mud, or in covered baskets, the main point to keep in mind being that the portion of the parent removed with them shall not dry up to the extent of losing the faculty peculiar to living wood-fibre of rapidly conducting water. Nevertheless there are some species, *e.g.*, sissu, the roots of which enjoy such remarkable vitality, that the parent root-segment can stand complete exposure in a moist atmosphere for many hours and even one or more days if only the leafy portion is limited or has been freely pruned or even entirely removed. Suckers of such species may be treated almost like cuttings and rhizomes.

ARTICLE 3.

PACKING AND TRANSPORT OF CUTTINGS.

Cuttings always consist of sections of well-lignified branches. Hence, if they have been deprived of their leaves, they dry up so slowly that they retain their vitality as long as the buds and cambium remain alive. It is evident that those cuttings which are already covered with secondary bark, the very best protection we can have for the cambium and the buds, will possess the greatest vitality of all.

Cuttings, therefore, generally require very little special care in being packed for transport. Moreover, being usually very straight, they take up little space and are easily arranged. For long or hot journeys they may be tied up in bundles like seedlings, or packed tight in covered baskets lined with moss or some other soft green stuff, especially if they still retain the greater portion

of their foliage. Otherwise they may be simply piled up in a wheel barrow or waggon or in open baskets, if they are small, or made up into bundles like faggots and carried on the head or in an ordinary bullock cart.

ARTICLE 4.

PACKING AND TRANSPORT OF RHIZOME-SHOOTS.

Rhizomes that have not yet sprouted, partake of the nature of seeds in that they contain within themselves all the elements for the formation and development of the roots, stem and leaves of the future plant. And even when they have sprouted, they possess this character to a more or less considerable degree. Where the resemblance with seeds ends and a difference begins is that, whereas the latter may lose without detriment the greater portion of their moisture, the former must always have their tissues very appreciably moist. Their vitality is generally greater than that of cuttings in that their lower nodes, as well as the entire rhizome portion, contain numerous developed and embryo roots that can stand a great deal of exposure, and in this respect they resemble suckers.

Rhizomes that have not developed aerial shoots may therefore be carried a day's journey without any surrounding soil and without any further precaution than that of shading them from the sun. For long journeys they are best put into baskets as close as possible, the empty intervals being filled with fine soft earth, which should also cover them up entirely. Protected from the light, they may be kept thus for weeks.

In the case of rhizome shoots, if they form little clumps and are not more than 3 feet long and ½ inch thick, they will retain their vitality in double-headed bundles much longer then seedlings. If they are larger, the rhizome portion should, for long transport, be surrounded with soil put in after they have been carefully arranged. For short journeys they require no further protection than shading from the sun and freedom from contact with dry air.

SECTION X.

Care of transported planting material before use.

It nearly always happens that at places situated at some distance from the nursery or other source of planting material, more is received than can be put out at once, and even when the distance of transport is short, unexpected hot sunny weather or night-fall puts a temporary stop to the work of planting and prevents an

appreciable quantity of the material from being used the same day. Hence the necessity of knowing what to do in order to keep the plants in a healthy and vigorous condition until they can be put out or are actually wanted.

When a large consignment is received from a distance, especially if they have gone through a trying journey, they should be unpacked without delay. Rooted plants, whether with attached soil or not, should be at once put into the ground in long pits or trenches in a shady place and copiously watered; plants that have been headed off or unsprouted rhizomes may be completely buried. Unschooled cuttings may be thrown into water or buried in the ground either completely or up to the top second or third bud. From day to day only the quantity actually required should be taken out, and if the material cannot all be used up for some time, what is kept in pits or trenches should be watered as often as the soil round it begins to get dry. In the special case of plants transported with a well compressed protective ball of earth round their roots, but which ball of earth is not to be put out with them, it may be found necessary to wash away the earth in water and then at once to put the plants into the trenches with naked roots. Under exceptional circumstances it may happen that a part of the material has to be kept over until the following season, in which event this surplus stock will have to be planted out as in nursery lines in temporary nurseries, care being taken to previously prune off all damaged parts and to throw away whatever is unfit to be kept.

In the case of sudden sunny or dry weather intervening or night coming on, the still unused material may be similarly put into pits or trenches in the forest, or, if little pools of water are handy, it may be kept more or less submerged in the water.

SECTION XI.

Method of planting.

Whatever mode of planting is adopted, the main object to aim at is so to put down the planting material that it will strike and establish itself as quickly as possible. Hence the method of planting will in each case depend on the kind of planting material used, on its age or size, on the species to which it belongs, and on the nature of the soil and locality.

The following scheme exhibits at a glance the different methods of planting ordinarily followed:—

- PLANTING.
  - IN THE GROUND.
    - FLUSH WITH the natural surface
      - in PITS
        - With a ball of earth (*Ball planting*) ... 1
        - With naked roots (*Pit planting*)
          - without manure ... 2
          - with manure ... 3
      - in HOLES 4
      - in NOTCHES
        - in single notches ... 5
        - in cross-cut notches ... 6
    - BELOW the natural surface
      - in HOLLOWS 7
      - in TRENCHES 8
    - ABOVE the natural surface
      - on MOUNDS 9
      - on PLATFORMS 10
      - on RIDGES 11
  - ON TREES 12

In whatever way we plant in the ground, rooted plants should always be buried down to at least the point up to which they were covered before (they may of course be buried an inch or so deeper, in

order to protect the collum buds and the sensitive base of the stem), and their roots should be allowed to occupy severally more or less the same relative position as before. Unschooled cuttings will be put down in the same manner as in nurseries (see pp. 208-210), And, in any case, all damaged or otherwise unpromising material. regarding the success of which there is any doubt, should be thrown away.

ARTICLE 1.

BALL PLANTING.

PREPARATION OF THE PITS. Whatever the size of the pits into which the plants are actually put down, there is nothing to prevent us from working the soil as deep and over as great a width as may be required, 1stly, in order to favour the rapid downward and lateral extension of the roots, 2ndly, to prevent too early contact with the roots of the surrounding vegetation, and 3rdly, to break up and improve a bad subsoil. In thus working up the soil, strong and other hurtful elements may be removed and fresh soil of good quality added.

In the case of plants lifted up with a conical or semicircula. transplanter (Figs. 49 and 50), the pit should, as already recomr mended in connection with nursery lines (p. 202), be made with a similar implement of the same shape and size. Otherwise the khurpa or trowel, or hoe or ordinary spade should be used. If the soil in which the pits are made has not been previously dug up, the soil at the bottom of the pits may be specially loosened.

PUTTING DOWN THE PLANTS. In the case of pits made with the conical transplanter the ball of earth surrounding the roots should be slipped in, contact between the ball and the surrounding soil being effected, according to the stiffness of the latter, by beating with a light wooden mallet or by pressing with the foot. Unless the contact is thoroughly secured, the ball of earth must in the ensuing dry weather, contract, the sides of the pit at the same time receding. The result will be the formation of a crevice whereby the newly developed rootlets will get completely exposed, if they are not snapped in two should the soil be at all hard or stiff.

If the pits have been made with any other implement, they will necessarily be considerably wider than the ball of earth, so that

when the plants are put in, an appreciable vacant interval will be left between it and the sides of the pit. This interval should be filled up with good finely broken soil well rammed in, and the entire ring of new soil should be covered with turf, stones, &c. in order to protect it from drought and thus prevent it from shrinking and opening out along the line of junction.

If the soil has been dug up previously to the excavation of the pits, contact with the ball of earth is easily effected and more securely maintained. If the soil has not been previously dug up, but that at the bottom of the pits has been loosened, it is necessary, before putting in the plants, to press down the loosened soil; otherwise its subsequent settling must afterwards disturb the ball of earth, thereby destroying its connection with the sides of the pits and breaking or in some other way injuring the new tender roots formed since the planting.

In dry soils the depth of the pits should always slightly exceed the height of the balls of earth round the roots of the transplants, so that a hollow may be formed round each plant to catch and retain rain water and also to facilitate watering.

VALUE AND EMPLOYMENT OF THE METHOD. In this method success depends, first of all, on the proportion of the original mass of root fibres and hairs left in the ball of earth. Now the larger the plant, the smaller must this proportion be, unless indeed the ball of earth was so large as to render the cost of transport, if not also of extraction and putting out, entirely prohibitory. Hence the method is rarely suited, as regards forest purposes at least for any but small plants and the lowest category of those of middle size.

In the next place, success depends on the completeness of contact between the ball of earth containing the roots and the sides of the pit. This contact is extremely difficult, if not impossible, to secure in stiff or hard soils, which undergo strong shrinkage or expansion according to the amount of moisture in it and in the atmosphere. Hence the effectiveness of the method is necessarily in proportion to the free nature of the soil.

Provided the two conditions just discussed are favourable, ball-planting is usually the most certain of all possible methods, since in it the roots suffer a minimum amount of injury. It yields excellent results in sandy soils, whether these are moist

and even wet or very dry or entirely wanting in cohesion; also in frosty localities and where destructive insect grubs abound. And it is the best method to adopt in areas in which the soil changes so abruptly from point to point that no one of the other methods of planting can be uniformly employed there.

It is not adapted for shallow or stony soils. The well-nourished soft-tissued and therefore delicate roots of the plants, still contained within the rich original soil, continue growing in the same generous manner as before, but the moment they reach the rock or stony soil immediately outside, they receive a sudden check, which is moreover aggravated by the extreme sensitiveness of the rocky and stony elements to the rapid sub-aërial fluctuations of temperature, and, if the subsoil is impermeable, also by the excessive moisture after a fall of rain. This sudden check is obviously fatal to the vitality of the new roots and to the general vigour of the entire root-apparatus. But the effect on the crown is even worse, for the crown continues, even after the roots have ceased to grow, to expand rapidly at the expense of the reserve matter in the plants; and, when this is at length exhausted, the succulent, imperfectly lignified extremities of the overgrown twigs and branchlets suddenly wither up and die. This reacts on the already weakened, diminished and unhealthy root-apparatus. The end of it all is that the plants either die directly or reach such a condition of debility that they easily succumb to other causes of injury, or become hide-bound and unable to make any appreciable progress.

Ball planting is also unsuited for very stiff soils, except such as remain constantly moist.

The chief objection to the method lies, however, in the great cost not only of lifting up and transporting the plants, but of raising them, for the large quantity of rich, highly prepared soil removed along with the roots has to be replaced, and the inevitable wide spacing of the individual transplants necessitates large nurseries. Nevertheless by using only small plants (yearlings and even germ plants), the cost can be very considerably diminished, and a further reduction can be effected by employing temporary instead of permanent nurseries.

ARTICLE 2.

PIT PLANTING WITHOUT MANURE.

PREPARATION OF THE GROUND. As in the case of ball planting, the soil in which the pits are made may be previously dug up;

but if it is judged necessary or desirable to loosen the soil beyond the actual spread of the roots, it is better to at once excavate a larger pit than is just sufficient to hold the roots. In rich loose soil the pits need never be more than a trifle larger, and the amount of extra excavation, especially in respect of depth, will increase with the stiffness, poverty and want of depth of the soil and the extent to which it is traversed by a network of refractory invasive roots. In any case, the excavation must go below the depth reached by such roots. The tools to use will of course differ with the nature of the soil, the size and abundance of the roots in it, and the depth of the pits. Deep narrow pits in soil free from stones would be most easily made with an auger (Figs. 94 and 95) or a boring machine (Fig. 96).

The excavated earth should be collected alongside each pit in three separate heaps, one consisting of the good soil taken from the top, the second of the inferior soil from below, and the third of the stony element. All fragments of roots should be thrown away.

The pits would, as a rule, be dug just before the plants are put in, especially so in dry soils or in wet situations where the excavated earth is likely to get washed away. But if the soil is very stiff or full of sour humus, the pits should, if possible, be prepared some time previously, in order to freely expose the excavated earth to beneficial atmospheric influences.

PUTTING DOWN THE PLANTS. We will first consider the most common case, *viz.* of plants with bushy roots short enough for the workmen kneeling on the edge to reach the bottom of the pit. The plant, being put in, is held in position with the left hand, while the roots are carefully arranged with the right hand. With the same hand the good soil is gradually and gently dropped over and round the roots, any roots getting out of position during that operation being placed right again, and the plant being from time to time gently agitated so as to allow the loose soil to slip in between and amongst the roots and leave no air spaces. After the good soil has been used up, that from the inferior heap is then put back into the pit, until the plant is covered up to the point required. Should the good soil be originally insufficient, some more must be added from the surface immediately outside. When all the roots have been covered, but before the pit has been quite filled, the soil is pressed down with the hand as it is put in; and when the pit is full, a final pressing with the

hand or foot, whichever is more effective, is given in order to prevent any subsequent settling, which would not only mean imperfect original contact between the soil and the roots and the consequent drying up of many of these latter, but also the ultimate exposure and, may be, death of the upper ones. Last of all, some of the stony element may be spread over the already filled pit in order to help towards preserving the moisture of the soil below. In most parts of India it is advisable to plant a little deep, so as to leave a slight hollow over the roots to catch and retain rain water.

If the plants to be put down possess mainly a long tap-root with scarcely any side roots, the manipulation is obviously very much simpler. Such plants are used solely in order that they may at once get into soil beyond the reach of the dense net-work of roots of grasses and other injurious vegetation. Hence, by putting in the good soil at the bottom of the pit and the inferior portion above, all root-activity is forced into the lower extremity, where indeed it is required. In Oudh, Captain Wood has planted in this manner sissu seedlings with a tap-root up to 6 feet long.

The workmen must always be supplied with some tool, like a khurpa or trowel or small weeding fork or a light one-hand hoe, wherewith to break up clods (for only finely broken soil should be put back in direct contact with the roots) and, if necessary, also to clear out or enlarge the pits.

VALUE AND EMPLOYMENT OF THE METHOD. This method is an extremely simple one, and is adapted for all sizes of plants, especially for those of the two higher classes. It can be employed in almost any soil, very wet or very shallow soils excepted, in which indeed no method of pit planting can ever be successful. The roots being free and not confined, as in the case of ball planting, each plant is free to assume its own style of root-development in accordance with its surroundings. In short this method may be considered as the best one to adopt under all ordinary circumstances, particularly when large plants are used or the plants possess a strong and extended ramification of roots.

ARTICLE 3.

PIT PLANTING WITH MANURE.

Owing to the use of manure, the pits are necessarily made smaller than in the preceding case, both in order to save manure and because the manure brings plant-food within easy reach of the

roots. They may be made with augers (Figs. 94 and 95) or with conical transplanters with a long blade. The last mentioned tool would be the most handy, if the soil, as is often to be recommended, has been previously worked up. In other respects the procedure is similar to that in the preceding case.

PUTTING DOWN THE PLANTS. The manure used must be either surkhi ash prepared from a loamy or clayey soil, or unburnt loam or clay mixed with wood ash or with any other manure. Clay and loam, or, expressed in more general terms, a clayey earth is employed instead of a sandy soil simply because the former retains the manure sufficiently energetically to prevent rain water from carrying it away and the plants from taking it up too rapidly and thus assuming an abnormal rate of growth, only to succumb as soon as it was exhausted. This is also a reason for using only weak manures (Fig. 105, *a*)

A handful of the manure is first put up against one side of the pit. The plant is then set up against this manure and another handful (*b*) is dabbed on, on the opposite side. The rest of the pit is now filled up with ordinary soil (*c*) and the whole is then pressed down with the foot in the direction indicated by the arrow.

VALUE AND EMPLOYMENT OF THE METHOD. The use of the manure has obviously the effect of an early and vigorous development of roots and the rapid striking of the young plants, a circumstance specially favourable for material raised in the rich well-prepared soil of a nursery. But it is evident, from the mere description of the method, that it is adapted only for small plants or at the outside for the lowest category of those of middle size, and it is an essential condition of the method that manure shall be available in abundance and at cheap rates. The method is especially suitable for putting out bamboos and teak and other species, which, like the teak, develop at first a thick strong taproot with only a few insignificant side roots. It is of course impracticable in shallow soils with a hard or impermeable bottom.

ARTICLE 4.

PLANTING IN HOLES.

PREPARATION OF THE SOIL. The essential characteristic of this method is that the planting material is inserted into narrow holes made with an ordinary stake or the soil dagger (Fig. 82) or the stake dibber (Fig. 83) or the mallet dibber (Fig. 84), or with some similar implement. The soil in which the holes are made

may, if necessary, be previously ploughed or dug up. If the lines of holes are close together, and the plough can be used, the entire area may be cultivated in this manner before being planted up. When there has been no previous tillage, it may be necessary to cut or shave away strong weeds and bushes for a foot or so round the planting places. In any case, the holes will never be made except just before the planting material is put in. The depth of the hole must obviously be at least equal to the length of the portion of the plant to be buried, but it may of course be greater, in order to encourage the rapid downward extension of the roots, and the excess depth should then be filled with good soil or manure.

PUTTING DOWN THE PLANTS. If the hole has been made with the soil-dagger, it need not be filled up at all, but closed over the portion of the plant to be buried by pushing the same implement into the ground close to the original hole, as shown in Fig. 106, and then, by simple leverage, pressing the intermediate earth up against the plant until the two opposite edges of that hole meet. To render the result more certain, the second hole may also be closed in the same manner as the first by a similar manipulation of the dagger.

In any other case the holes are filled up with good soil or with manure. In putting down rooted plants into the holes, the thin flexible roots, especially the extremities, may get caught up against the sides of the holes, and thus cause waste of time and temper. To prevent this mishap, the roots should be dipped into thin mud or manure just before being put in; the light slender roots thus get sufficiently weighted and slip into the the holes without any bending or twisting.

VALUE AND EMPLOYMENT OF THE METHOD. Under a canopy of high trees, in a naturally loose rich soil, this method will yield excellent results; also if the soil has been previously worked up and the material used consists of cuttings of species that strike easily or of seedlings that belong to species which, like teak, produce a long vigorous taproot, but cannot generally be successfully transplanted except as germ seedlings. Under these circumstances, it can be used in almost any soil, as long as this is not rocky or a very stiff clay, or is not liable to be overrun with strong weeds. In places where climatic extremes do not prevail, it is specially well adapted for sandy soils in large open wastes, in recent coupes, &c. It is the only method employed for cuttings of the class of unpruned rods, and even posts may be put out by it in favourable

soils. But the method requires much daring in the conception combined with great judgment and resource in the execution. When it succeeds, the first cost is hardly greater than that of direct sowing, while the cost of repairs and maintenance is markedly less.

ARTICLE 5.

NOTCH PLANTING.

This method resembles very closely that just described, from which it differs only in that in the latter it is a more or less round hole that is made, whereas here it is a cut of some length.

PREPARATION OF THE GROUND. Just like holes, notches may, according as the soil is naturally loose and free from injurious weeds or is stiff or hard or traversed by the roots of strong weeds, be made either in totally unprepared soil or in soil that has been worked up. Similarly, although the soil may not have to be previously cultivated, contiguous weeds and bushes may have to be shaven away.

The length and depth of the notches will depend on the size of the plants and the number put down in each. The implements will of course vary with the size of the notches to be made. For small plants put down singly a hoe with a long narrow blade (Fig. 87) would be used with economy. In all other cases the notching spade (Fig. 85) should be employed.

At each point either only a single continuous notch may be made, or two notches may be made in the form of a T or of a cross. The single notch and the cross-bar of the T should be made slightly obliquely, the latter inclined in the direction of the upright bar. In the cross-cut notch, both cuts should be oblique. Oblique notches are not only easier to make, but they facilitate the pressing down of the earth after the plant or plants have been put in.

PUTTING DOWN THE PLANTS. In the single notch the plant or plants, if more than one are used, are inserted in the middle or are evenly distributed, and the notch is then closed with the pressure of the foot, assisted, if necessary, with the weight of the body. In T or cross-cut notches, it is usual to put in only a single plant, and that is placed at the intersection of the two notches, which are closed, as before, with the pressure of the foot. To aid the insertion of the fine, pliable tap-root of small seedlings, the plan of dipping it in thin mud, as explained under the preceding system, is adopted. It is superfluous to add that the plants should be put in as soon

as the notches have been made, otherwise, owing to the drying up and hardening of the sides, it will be impossible to close them in a complete manner.

VALUE AND EMPLOYMENT OF THE METHOD. This method possesses all the advantages of the preceding one, to which it is besides superior in that it cuts through a certain length of the soil and the roots that traverse it, and thereby gives a better chance of development to the roots of the plants put down. On this account it may have a more extended application than that method. For instance, in stiff soils, where the latter would invariably fail, the notch method may sometimes succeed. In stony soils its employment is obviously restricted to those places where the narrow-bladed hoe can be used.

ARTICLE 6.

PLANTING IN HOLLOWS.

This method differs from the ordinary pit method only in that the plants are set down an appreciable depth below the natural level of the ground. Hence the pits are made and the plants put down in the same way as in that method, except that the depth of the pits is proportionately greater.

VALUE AND EMPLOYMENT OF THE METHOD.—This method is specially adapted for very dry soils or very dry and hot climates and stands, as regards its employment and its advantages and disadvantages, in the same relation to pit and ball planting as pit or hollow sowing stands to patch sowing.

ARTICLE 7.

TRENCH PLANTING.

PREPARATION OF THE GROUND. The trenches are prepared in the same way and with the same tools as trenches for sowing but, as is obvious, considerably deeper. As in pit planting, the good topsoil should be kept separate from the poorer excavated portions, and that again separate from the stony elements. If necessary, the soil at the bottom of the trenches may be loosened.

PUTTING DOWN THE PLANTS. The trenches being obviously very costly and their sole object being the protection of the plants against excessive insolation, drought and frost, only small plants or the lowest category of middle-sized plants are actually used. Such plants may be put down either as in the preceding method or with the aid of dibbers. Culms would of course be best

laid down flat, as already described on page 210. Unpruned rods also may be put down in the same manner, but they will previously have to be notched at various points to encourage the development of roots, and the extremity will always stand out of the ground. The trenches may either be filled up to the top or be only partially filled.

VALUE AND EMPLOYMENT OF THE METHOD. Trench planting is suited for dry porous soils and for localities where there is danger from sun or frost. But as it is an extremely expensive method, its use must be confined to the reboisement of dry slopes where sowing or other methods of planting would not yield sufficiently quick results.

The trenches catch and retain water coming down from above, and if culms and other cuttings have been put down, these form, with the shoots and roots that they develop, a single compact mass which holds the soil together and also impedes a too rapid subsurface drainage.

ARTICLE 8.

MOUND PLANTING.

PREPARATION OF THE MOUNDS. Each mound may be built up directly with soil scraped or cut from the immediately surrounding ground, or with soil specially prepared to suit the species to be planted. The foot of the mound may be flush with the natural surface of the ground, or the mound may be surrounded with an excavation like a moat (Fig. 107), which, besides helping drainage, necessarily adds to the size of the mound and thus reduces the amount of earthwork. Or the mound may be built up in a hollow (Fig. 108) in order to provide against drought. The height of the mound above the natural surface of the ground will seldom exceed two feet, but in very wet localities, where also very high weeds grow, it may, if considerations of expense allow, attain 3 and even 4 feet.

PUTTING DOWN THE PLANTS. If the mound is not too large, a plant with naked roots may be put in by cutting the mound across and inserting the roots between the two halves, which should then be at once brought together again. If the plants are large or have a ball of earth round their roots, an excavation must be made at the top of the mound to receive them, and the plants put in

without delay. Indeed, if the ball of earth is large, it may be put down first and the mound then built up round it, as shown in Fig. 109.

To consolidate the sides of the mounds they may be revetted with stones or covered with sods of turf. The sods should be as large as possible and cut in the shape of broad sectors of a circle; and, in order to anticipate the inevitable shrinkage, they should slightly overlap one another.

VALUE AND EMPLOYMENT OF THE METHOD. This is the most expensive of all the various methods of planting, excepting perhaps the ridge system (to be treated lower down). Hence it should be avoided outside the two following cases :—

(i) *When the soil is extremely wet and the cost of draining is prohibitive.*—In that case the mounds should be built up directly on the natural surface of the ground, a surrounding moat if necessary, being made in order to supply the whole or a great part of the earth required to raise the mound as well as to diminish the absolute height to be built up. The India rubber tree has often been planted in this manner on mounds up to 4 feet high. The position of the roots in the mound guarantees them against damping off, and they finally reach the wet natural soil only when they, and with them the plants, have become strong, large and woody enough not to suffer from the presence of excessive humidity.

(ii) *When the soil, although very wet and badly drained during the rains, is otherwise dry.*—In this case the mounds should be built up in a hollow and their apex should hardly stand up above the natural surface of the ground. The hollow surrounding the mound will catch and retain water for the benefit of the plant in the mound, which it will at the same time drain sufficiently for the purposes of root-aëration.

Experience in the Alps in Europe has shown that cattle do less damage to plants on mounds than to those put out in any other manner.

Mound planting will possibly be found to succeed where frosts are very severe, the high position of the plants acting as a safeguard. It will invariably fail where the soil is very stiff or hard, or is shallow and rests on an impermeable bottom, or the ground has a pronounced slope, in which last case the mound would be washed away. Unless the species to be raised are very rapid growers from their earliest age, only middle-sized and larger plants should be used.

ARTICLE 9.

Platform planting.

Preparation of the ground. Near each planting spot a square pit is dug and the excavated earth is heaped up along one side in the shape of a square platform. Owing to the soil being then soft and also in order to expose it to beneficial atmospheric influences, the platforms should be made immediately after the close of the rainy season. The depth of the pits, in other words, the height of the platforms will vary from 6 inches to 2 feet and the side of the square from 2 to 4 feet. The best portions of the excavated soil should be placed in the middle.

Putting down the plants. The plants should be put down in the centre of the platforms in the same manner as in the hole and notch systems, and sometimes in the same manner as in the pit system with manure.

Value and employment of the method. In wet soils this method enjoys the same advantages as the mound system, to which it is besides superior, firstly, because the roots get better aërated and, thanks to the draining effect of the pit, can go into the natural soil at once; secondly, because it gives less trouble and is less expensive; and thirdly, because it can be used on hillsides, the platform being protected from erosion by the pit, which, being made on the upper side of the hill, catches the surface drainage and prevents it from washing up against the platform. For the last reason, it is to be recommended on dry hillsides where there is no danger of erosion. In dry soils the platform is superior to the mound built up in a hollow; and where pit planting is successful, this method may be used with still better results by reason of the open pit, which catches and holds rain water and encourages the downward extension of the roots, and of the raised platform, which remains more or less free of weeds But it is, under those circumstances, adapted for use only in fairly rich soils.

ARTICLE 10.

Ridge planting.

Preparation of the ground. The ridges are prepared in the same way as for sowing (p. 266), except that they would generally be made both higher and broader.

PUTTING DOWN THE PLANTS. The plants are put into the ridges with a soil dagger (Fig. 82) or other light dibber (Fig 83), and with the same precautions as those described under hole planting (p. 320).

VALUE AND EMPLOYMENT OF THE METHOD. This is a very expensive and wasteful method and is only suited for irrigated land or in the reboisement of dry slopes, in both which cases a trench should be excavated along the upper side, and the excavated earth used in building up the ridge.

ARTICLE 11.

PLANTING ON TREES.

This method can be used only for the propagation of epiphytic species, such as most of the wild figs. By its means we obtain in a comparatively short time a lofty tree, and in dense forest especially where the living ground covering is very thick, admit, the planted epiphyte at once to the full benefit of light. Under very favourable circumstances the plants, which should be neither too small nor too large, may be simply tied inside a convenient fork close to the stem of the supporting tree. But it is always safer to make an excavation at the required point in the tree, fill the hollow with good soil, and then plant the young fig in the soil.

SECTION XII.

Maintenance operations.

The operations required to maintain a plantation until it is established may be one or more of the following:—protection against animals, against frost, against excessive insolation and against dangerous winds; watering, weeding and hoeing; training and repairs.

The measures to take against animals and unfavourable weather influences are of the same nature as those adopted in the case of direct sowings, there being however a difference of degree, since plants put out have, as a rule, all passed that tender age when they not only have numerous enemies but succumb easily to their attacks as well as to other extraneous causes of injury.

As regards watering, that operation will generally be less urgent in plantations than in direct sowings owing to the deeper rooting of the plants and their superior lignification. But, as

will be seen when we compare the two methods of artificial regeneration, plantations are often made in the driest soils, where success by means of direct sowing would be doubtful; in such places watering could seldom be dispensed with, especially during the first dry season following the planting. Watering cannot be avoided also when, owing to insufficient early rains, the plants have had to be put out so late that they have not struck sufficiently well to be able to resist the October heats and the severe cold of the immediately ensuing winter in upper and central India. In that case, the plants should be watered at least once after the rains have ceased, so as to enable them to tide through the trying damp heat under a clear sky, and, if there is a true winter, to become woody and advanced enough to resist the cold nights that follow.

With respect to weeding and hoeing, it must be remembered that as the plants can be put down only after a part of the season of vegetation has already passed, any growth of weeds that may subsequently be produced cannot, *cœteris paribus*, be as tall or as dense or strong as those that come up in the midst of direct sowings. Moreover the young plants are always stronger than mere germinating seeds and begin by having the start of the weeds. Hence, during the first season at least, weeding would generally be a luxury, except in the case of species which, like teak, are put out as mere germ seedlings and cannot survive root-contact with other plants. During the following years the plants, even if they do not absolutely require it, will generally be greatly benefitted by the complete removal, at the beginning of each growing season, of all vegetation immediately surrounding them, and this as long as they have not begun to overtop or of themselves to suppress the latter. Hoeing is seldom necessary, but is always very desirable at the beginning of the growing season in order to give the plants a good start, the benefit of which is retained all through the season. The hoeing and weeding should be combined into a single operation.

Many of the plants may sicken and languish; if such belong to broad-leaved species, they should be cut back in order to shoot up vigorously again. Many assume abnormal shapes, which may affect injuriously their vigour as well as their capability of growing up into well-shaped timber; these should be pruned in the same manner as plants in nurseries (pp. 205- 206).

Casualties must be filled up on the same principles as in direct sowings.

CHAPTER VI.

DIRECT SOWING AND PLANTING COMPARED.

Whether to sow or to plant in any given case is a question that does not always admit of a ready or a certain answer, particularly in a continent like India with its every imaginable variety of soils and climate and its enormous number of woody species, including more than a thousand important ones, some of which are distributed over a wide horizontal as well as vertical range and often undergo, with change of station, almost specific modifications of both habit and requirements.

The essential difference between the two artificial methods of creating or regenerating forests lies in the fact that in the one the seeds and, after them, the resulting seedlings are exposed to every possible risk and danger in the most exaggerated form, whereas in the other we use only material that has either not to pass through (cuttings, rhizomes and root-suckers), or has successfully passed through (seedlings), the most critical period of plant-life, viz., that including the seed and germinating stages and the time immediately following germination; and not only this, but in many cases the plants are of an age and size to be on the point of becoming established. But, on the other hand, whereas in direct sowings the seedlings are able to adapt themselves, from the moment they are produced, to the surroundings in which they are to pass all their existence, in planting, on the contrary, the seedlings and other schooled material, after being carefully fostered and more or less forced, or at least after having been growing under favourable conditions, receive first of all a shock to their growth in being lifted up, transported and handled about while being put into the ground, and may then be given perfectly dissimilar surroundings, to accustom themselves to which a severe call is made on their adaptiveness, some species being frequently unequal to this effort. Keeping these two essential distinctions in mind, we may now proceed to compare the two methods from the several points of view of (i) soil and locality, (ii) absence or presence and abundance and size of advance growth, (iii) density of the leaf-canopy overhead, (iv) amount of shade and shelter available, (v) the nature of the species to be used, (vi) special

prevailing extraneous causes of injury or destruction, (vii) quantity and quality of labour at one's command, (viii) mode of development of the crop, (ix) early realisation of marketable produce, (x) early formation of the desired type of forest, (xi) object to be fulfilled, and (xii) cost.

I. Soil and locality.

Experience has proved that in unfavourable soils and localities, particularly those in which young plants are liable to various causes of injury or to be kept back in their growth, planting is nearly always preferable to sowing; and the reason of this is obvious from the essential difference considered above between the two methods. In very moist or wet soils, in those which are stiff, cold and exposed to frost, as well as in those which are very free, easily dried up or poor at the surface, also in all soils that are liable to be overrun with a tall rank growth of grass and other weeds, planting must be the rule. And similarly, where extremes of climate prevail and endanger the existence of the tender young seedlings, planting will in most cases give better results. Thus if seed is sown directly where the distribution of the annual rainfall is irregular and fitful or limited to only a very short period of the year, the tender plants just emerging from the seed-cap may be killed by a sudden unexpected break of hot sunny weather, or the young seedlings may not have sufficient time in which to strengthen themselves against the severe season immediately following the rains.

On the other hand, if the soil and locality are of an average character, *i.e.*, neither too wet nor too dry, neither too stiff nor too free, neither too warm nor too cold, neither entirely devoid of vegetation nor yet thickly overgrown with weeds, and so on, sowing may prove as successful as planting, and, being cheaper, would be preferable. Again, the soil may be so changeable, that if we planted, large seedlings would be required at one point, middle-sized ones at another, small ones at a third, pit planting here, ball planting there, and so on, the conditions varying so rapidly and unexpectedly from place to place and point to point as to confound the most experienced and careful judgment. Out of such a dilemma there is only one mode of escape, *viz.* to sow. In the next place, the soil may be so unfavourable for the growth of the species to be used as to give a fatal shock to transplants from a nursery. In that case also we must sow. Against sowing it might be objected that temporary nurseries made in the middle of the area to be stocked will furnish the very transplants

required; but it is indisputable that seedlings raised in such nurseries will be still less able than the more vigorous ones from permanent nurseries to stand the shock of being lifted up, transported and put down again. Lastly, the ground may be rocky or so covered with boulders that planting would be a physical impossibility. Even if pits could be excavated in the rock, they would fill with water in the rains and cause the roots of the transplants to damp off; while amongst the boulders no room could be found for their numerous spreading roots or their single long tap-root, as the case may be. On the other hand, the young seedlings sprung from direct sowings will develop in proportion to the suitability of their surroundings; where there is hard rock, there they will send down a few slender roots that will insinuate themselves into the most minute crevices they may meet, while amongst the boulders those roots, into which the entire energy of the plants is concentrated, will soon force their way between the loose stones and ramify and spread themselves out in proportion to the quantity of soil they find there.

II. Absence or presence, and abundance and size of advance growth.

If there is no such growth, then the question of sowing or planting will be decided entirely on other considerations. But such growth may exist and it may be found necessary to introduce among it a new species or increase the proportion of one or more that are insufficiently represented. In that case, should the existing growth be abundant and already of a certain age or size, then it will generally be necessary to put out plants of about the same size and vigour, for sowings would stand very little chance of escaping suppression; and sowings would be allowable only in the event of extremely shade-enduring or rapid-growing species being used or of the previous growth being completely cleared away from wherever the seeds are sown. If the existing growth is open or very young, the choice between sowing and planting will be determined in accordance with other prevailing conditions, particularly those of soil and locality and the nature of the species to be used.

III. Density of the leaf-canopy overhead.

Under a dense leaf-canopy sowings will generally succeed better than planting, for young plants sprung up *in situ*, growing from the very beginning under weak solar illumination, will require

much less light than transplants, which, if they have not hitherto enjoyed more or less free exposure to light, will at any rate need a certain very appreciable amount of light in order to recover from the inevitable injuries sustained in the planting operations. Under an open leaf-canopy, the choice between the two methods of propagation will be determined by other considerations.

IV. Amount of tree-shelter available.

As regards such shelter we may have either—

(i) Bare open land, that is, land neither containing any trees nor bordered by them; or

(ii) Land with tree-cover directly overhead, but no trees immediately bordering it; or

(iii) Land fringed with trees affording lateral shelter, but containing itself no trees; or

(iv) Land enjoying shelter both overhead and laterally.

1. *Bare open land.*

In this case it will make an appreciable difference whether the area in question is entirely detached from a forest or is in every direction within sight of a continuous mass of trees. In the neighbourhood of standing forest both the air and the soil will be moister and enjoy a more equable temperature, dews will be heavier and more continuous, and the more violent and otherwise dangerous winds will be tempered and may even be kept out altogether; but, on the other hand, the severity of frosts will remain unmodified.

The further away the forest is, the weaker will obviously be this tempering influence it will exercise, and outside a certain radius its influence will be *nil*. So that in completely bare open land there will be nothing to check wide and sudden fluctuations of temperature both of the air and of the soil, or to diminish the action of dangerous winds, or to prevent marshiness in the rains and drought in the dry season; if the gradients are steep, there will be no obstacle to erosion, and if the soil has been for any purpose loosened or broken up, there will be nothing to check the multiplication of insects.

Hence in bare open land the early formation of a leaf-canopy is always desirable, and becomes all the more urgent with widening area or increasing distance from standing forest. Consequently planting will there be the rule, save in the very exceptional case (*a*) of the species not standing being transplanted and being at once

hardy, rapid-growing and of quick and easy germination, and of the soil and climate being at the same of an average character, without any tendency whatsoever to extremes, and (*b*) of irrigation being available. For instance, on dry sunny open slopes in the Himalayas we may generally *sow Pinus excelsa*, but *plant* deodar, which may, nevertheless, be sown directly on northerly or north-westerly slopes that are not too damp or too cold for that species. Again, in those parts of the teak region in which frosts are unknown, that species, as it cannot bear having its taproot injured, but shoots up rapidly and stands drought well, will generally be sown directly.

2. *Land with tree-shelter only overhead.*

The effectiveness of this shelter will depend upon the number and size of the trees affording it, the depth and closeness of their crowns, the species to which they belong, and the number of tiers of growth composing the leaf-canopy. The effect of such shelter is to maintain the soil loose, rich and moist, to keep down weeds and to mitigate frost and other injurious weather influences, if not to render every condition favourable for germination and the prosperous vegetation of young seedlings. Hence where sufficient shelter exists, sowing may be just as successful as planting, and being less costly, would in that case be preferable. If direct sowings are made, it is evident that the requisite amount of shelter, both overhead and laterally (Case 3), must be maintained until the plants are quite established.

3. *Land with only lateral tree-shelter.*

In this case the area itself bears no trees, but is fringed with trees affording lateral shelter. It is obvious that the effectiveness of such shelter will depend on the width of the area and the height, width, closeness and position of the fringe of trees. We will therefore consider separately the case (*a*) of narrow bands cleared through standing forest, (*b*) of small scattered blanks, and (*c*) of large treeless areas with a narrow surrounding fringe of trees.

NARROW BANDS CLEARED THROUGH STANDING FOREST.—According to the amount of shelter required such bands may have tall standing forest on both sides or on one side only.

In these bands the action of frost and of dangerous winds is mitigated or completely checked, the sun's heat is tempered, wide and sudden fluctuations of temperature both above and under

ground are prevented, rain falls directly on the young plants and washes off the dust clinging to their leaves, the deposition of dews is unimpeded and heavy, the moisture of both the soil and the air is fairly well preserved, and the covering of dead leaves is retained in its place and is able to decompose and form humus. Besides, such lines do not afford good breeding places for insects.

Under these circumstances, if there is no danger of stool-shoots or suckers springing up from the exploited trees, we may of course sow or plant indifferently, as long as other considerations do not rigidly fix the choice for us. If the appearance of stool-shoots and suckers is unavoidable, then we *must* plant, save in the very exceptional instance of an extremely shade-enduring species that is able ultimately to pierce the dense low cover of coppice, in which case we may for the sake of economy sow.

SMALL SCATTERED BLANKS. These may be places where previous artificial or natural regeneration operations have failed, or they may be little openings produced by windfalls or other accidents, or they may be clearings purposely made with the object of regeneration. In the first case, all the shelter that is available is afforded only by the surrounding growth, which can obviously have little effect in moderating injurious soil and weather influences, and we must therefore, generally plant, even independently of the considerations discussed under Condition II. In the other two cases, the shelter will be far more effective than in cleared bands of the same width, and the extent of the opening may be so slight as to render possible the early restoration of the leaf-canopy. Here then we must plant or sow according to the abundance and size of the advance growth (Condition II) or, in the absence of advance growth, according to the necessity of getting up a strong new generation early or late (Condition XI); but if the blank has existed long enough for the soil to have begun to deteriorate, then planting may be found preferable to sowing independently of any other consideration.

LARGE AREAS FRINGED WITH FOREST. Such areas may be quite recent clearings or long-abandoned cultivation sites. If they are the former, then the choice between sowing and planting will depend on the number and vigour of the stools capable of producing shoots, the abundance and size of the advance growth, if there is any, and the nature of the soil, locality and species; and it will be found that the instances in which direct sowing is to be recommended, will be almost as numerous as those in which there is no alternative

to planting. If the areas belong to the latter category, it will be found that under the constant unimpeded action of hot and cold winds, frost and insolation, the soil has become hard and impoverished, and grasses and other weeds, both herbaceous and woody, have so taken possession of it, that the introduction of a forest crop is possible only on the condition either of the soil being thoroughly worked up and cleaned, or of strong plants, able to cope with, and master, the weeds, being brought in. Hence in such places planting will be the rule, direct sowing being adopted only in the case of species possessing exceptional vitality and tenacity and able to grow up rapidly.

4. *Land enjoying shelter both laterally and overhead.*

Here shelter will generally be more effective than in either of the two preceding cases, and the choice between direct sowing and planting will be determined by the combined considerations discussed thereunder, the result being more frequent resort to the former method than is advisable in those cases.

V. Nature of the species used.

In deciding between direct sowing and planting we have first of all to consider whether the future crop is to be pure or mixed.

1. *When a pure crop is to be raised.*

If a pure crop is to be raised, the single species to be propagated must of course be one that is thouroughly suited for the soil and locality both as regards its general vegetation and the size which it is required to attain. But these are considerations entirely foreign to, and independent of, the present discussion, in which we are concerned only with the circumstances attending the first appearance and early growth of that species. Such circumstances are—

(i) *Form of root-system of the seedlings.* If the young plant develops a strong tap-root with little or no side-roots of any size, its transplanting, unless effected, as in the case of teak, before the tap-root has time to attain an excessive length, or unless each plant has, like sissu under the Wood system, been raised in a tube from which the long taproot can be taken out entire, cannot but be accompanied with the loss of a large proportion of the most active portion of its root-apparatus. Some species suffer less than others from so notable a diminution of their absorbing organs, while some are never able to recover from it. As regards the last class and those species which recover with

difficulty, we must either sow or use germ plants, and the final choice between these two methods will be determined by the other characters of the species. In the case of those species the young plants of which do not mind a severe curtailment of, the taproot, or which naturally develop a bushy mass of roots, the question of planting or sowing must be argued out on other grounds.

(ii) *Facility of germination.* If the seeds of any species germinate freely, then, other circumstances not being unfavourable, sowing, as it is more economical, would be preferable to planting. Seeds may germinate freely owing to one or more of the following causes : propitiousness of soil and weather, non-exacting nature of the seeds, more or less complete absence of enemies.

(iii) *Degree of hardihood of the young plants.* If the young plant is delicate and likely to suffer from prevailing weather influences, then sowing would be altogether out of the question, save where protection naturally exised or could be provided at a cost that is not prohibitive, as, for instance, under already existing forest, or under a preliminary nurse crop that pays for its own creation and maintenance, and so on. The more delicate the young seedling is, the older must be the transplant used. In the case of hardy species the choice between the two methods of regeneration will depend entirely on other circumstances.

(iv). *Degree of ability to bear shade.* This quality need of course be considered only when the new crop is to be established under standing forest or in the midst of a more less dense growth of weeds or shrubs, the roots of which cannot injure those of the species to be propagated. Under these conditions only a shade-enduring species would obviously be used and it would be sown or planted according as other prevailing circumstances demanded the one or the other mode of propagation. In the absence of heavy cover, the question of planting or sowing would be decided without any reference to the shade-enduring capacity of the species.

(v) *The number and vitality of the collum buds of yearlings.* The presence of strong and numerous collum buds will always enable the yearlings to resist more or less suecessfully unfavourable weather influences and hence the species could be sown if other conditions did not order otherwise.

(vi) *Rapidity of growth during the first years.* Species which grow up rapidly almost from the time they germinate, can often be sown, even if they are delicate, since they do not require shelter

for any length of time and that amount of shelter can nearly always be afforded without difficulty and at an insignificant cost. On the other hand, hardy species, if their early growth is slow, must generally be planted on account of the long time their seedlings remain small enough to be sensitive to atmospheric extremes and exposed to be otherwise fatally injured.

(vii). *Development and shape of crown.* Species which develop early a strong crown will generally be adapted for direct sowing, as the young plants, having a root-apparatus strong in proportion, will be able to hold their own against most weeds and be also able to recover easily from injuries due to the weather or to any other cause.

2. *When a mixed crop is to be raised.*

In the case of mixed forest the preceding six considerations still hold good, and in addition due attention must be given to the influence the various species may exercise on each other. Thus, to take a single instance, if a shade-enduring species is to be mixed with another that is shade-avoiding and at the same time a more rapid grower, the two may be sown together, provided there is otherwise no objection to direct sowing. But if the latter is a slower grower, then it must be planted at the same time as the other is sown, or, if both are planted, more advanced individuals of the shade-avoiding species must be used. Both may of course also be sown, the one a sufficient time before the other, if the leaf-canopy can be formed early enough not to endanger the fertility of the soil and its freedom from obnoxious weeds (see Rule III, p. 127). Other circumstances to note, besides the relative shade-enduring capacity of the species and their relative rapidity of upward growth in early age, are the relative mass and spread of their crowns and roots, the extent to which their root-systems are dissimilar, and the various degrees of suitability of the soil, climate and other extraneous conditions for the growth of young plants of the several species.

VI. Special extraneous causes of destruction.

We may say generally that seeds have more enemies than seedlings, and young seedlings run greater risks than older plants, which are at the same time more tenacious and resisting. Hence in respect specially of such causes of destruction, planting stands superior to direct sowing, which would be permissible only in the more or less complete absence of such causes.

VII. Quality and quantity of labour available.

Planting always demands more skill, closer supervision and

greater care than sowing, and it must be accomplished within a much more limited time (see p. 293, para. 3). Consequently success in planting depends on a sufficiently large trained and conscientious body of workmen being available at a moment's notice, and this all the more, the more unfavourable the prevailing circumstances are. Thus, for instance, if the season suitable for putting out is short and showers are fitful, or if the area is large, unless a sufficiently large gang of trained labourers under the supervision of an efficient establishment could be got together the moment they were wanted, most, if not the whole, of the area to be stocked would necessarily have to be sown directly. Again, in the interior of the Himalayas where little or no rain falls in summer, the only favourable time for planting is the extremely short spring between the melting of the snows and the setting in of the summer. This term may be too limited for planting, and sowing must therefore be largely, if not exclusively, resorted to.

VIII. Mode of development of the crop.

It is a fact, conclusively proved by experience, that a forest formed entirely of transplants seldom attains the same height as one raised directly from seed. The transplants, having been carefully raised and selected, and being, when put down, all of one and the same age and more or less the same size and strength, start up all together with more or less equal vigour and, as they grow up, keep more or less on a level with each other, so that there are no smaller neighbours to push up the taller and more promising individuals without narrowing and weakening their crowns by lateral pressure. The consequence is that the useful stage of the struggle for existence is not only necessarily a brief one, but must perforce be still further shortened by the forester himself in order to relieve the victors at once from the pressure of their all but equally-matched neigbours. On the other hand, the more prolonged struggle in a sown crop inevitably keeps back individual plants and results in diminished production, unless the forester intervenes early and frequently and maintains unchecked the growth of the stronger individuals, a task easy enough in itself, but requiring large establishments and money.

IX. Early realization of marketable produce.

In a plantation, the plants used being already of a certain size and strength, they obviously, from the very beginning, stand further apart than seedlings of the same size in direct sowings. The con-

sequence is that they maintain an unhampered development for a comparatively long time, and grow up with more or less uniform vigour, a result that is favoured by the fact of their having been all selected plants and therefore endowed with a high degree of tenacity. In a direct sowing, on the other hand, the struggle for existence not only begins early, but goes on between plants of various heights and of various degrees of vigour. Hence, although in a plantation the stems taken collectively may attain a given stage of development earlier, yet scattered individuals reach a marketable size earlier in a direct sowing. Moreover, whereas in the latter numerous stems, especially those which overtop their neighbours, may at all ages be removed without leaving any very perceptible or long-open gaps in the leaf-canopy; in the former, until a certain comparatively advanced age has been reached and some of the stems have then begun to get ahead of their companions, there is seldom any real reason for cutting out one individual rather than another, and not only this, but as the removal of any one from among them produces an opening in the leaf-canopy of the same size as the crown taken out and, therefore, requiring some time to close up, there is every inducement to delay the first intermediate felling. Lastly, the early produce furnished by a crop resulting from a direct sowing is generally taller, straighter, and less branched and knotty than similar produce derived from a plantation, a no small advantage in a country like India, in which there is such an enormous demand for small poles for round rafters, and the hot bright sun and several months of drought favour knotty growth.

X. Early formation of the desired type of forest.

It is evident that planting will produce the desired crop sooner than sowing, and the advantage in favour of the former will be all the greater, the larger the plants put out are, the more slow-growing in its earliest stages the species used is, and the more unfavourable for tree-vegetation the prevailing conditions are.

XI. Object to be fulfilled.

The object in creating a forest may be very various. Thus, it may be to raise a few scattered trees as quickly as possible on permanent pasture lands, in which case planting out the largest material practicable under the given circumstances will be the only advisable course; or it may be to introduce, or increase the proportion of, a given species in an already existing high forest, in which case the choice between sowing and planting will depend on the nature of the low growth, useful or other-

wise, that is already on the ground; or it may be to introduce a similar mixture into a copse or to assure therein a continuous supply of seedling shoots in order to maintain the quality of the regrowth, in which case planting will be the general rule; or it may be to raise a protective fringe of trees, where again planting will be almost invariably adopted; and so on.

XII. Cost.

In comparing the relative cost of the two methods, two things must be borne in mind. In the first place, it is certain that planting is, as a rule, subject to fewer failures, and hence involves a smaller outlay on repairs, the figure for which may often, in cases of indifferent success, equal and even several times exceed the first cost, so that the first cost alone is not a sufficient criterion by which to gauge the expensiveness of either method; and, in the second place, we know that as respect the first cost itself, the smaller the planting material is, especially if it consists of seedlings, the more nearly does planting in its results approach direct sowing, and that with increasing size or age of the transplants that figure increases, not in arithmetical, but geometrical ratio. But the question of cost must, under any circumstances, be subordinated to that of success, and becomes a deciding factor only when success is to be obtained by either method; and then too, if direct sowing is cheaper, the choice will depend also on the answer returnable to the question—Does the greater rapidity of results secured by planting at least compensate for the higher expenditure it involves? If it does not offer a sufficient compensation, we must sow, otherwise planting would be the method to adopt.

In India we have as yet no trustworthy data for comparing the relative cost of the two methods. In their absence the following figures, taken from Gayer and referring to Bavaria, will be found both interesting and useful. The average daily wage of a workman is taken at 8 annas.

Conifers sown in plough-made furrows, width of cultivated interval 4′	Rs. 6-8	per acre	
Scots' pine or silver fir sown in strips 2′ wide, uncultivated interval 4′	„ 8-14	„	„
Conifer yearlings planted 2′ apart in lines 4′ apart ...	„ 7-12	„	„
2-3 year old silver fir or Scots' pine planted 40″ × 40″ ...	„ 12-18	„	„
Ball-planting 3-4 year old silver fir, &c; distance of transport moderate	„ 16-24	„	„
Planting middle-size broad-leaved seedlings forced by repeated cutting back, 4′ × 4′	„ 24-50	„	„
Mound-planting of silver fir, 4′ × 4′	„ 28-44	„	„
Planting large seedlings (6-8 years old), 56″ × 56″ ...	„ 120-180	„	„

CHAPTER VII.

NATURAL REGENERATION BY SEED.

We know that in natural regeneration by seed the new crop must spring up exclusively or almost exclusively from self-sown seed. Now this seed may evidently either (i) be shed from trees standing immediately overhead, or (ii) come from trees standing outside the area to be sown, or (iii) be furnished by trees standing both inside and outside that area. Except in an isolated wood, that is so small as to be completely worked over in a single operation, the first case can, strictly speaking, never occur, since the trees surrounding the area to be regenerated must necessarily contribute a less or greater proportion of the seeds falling upon it. Hence, to prevent confusion of ideas, the first and third cases wil be dealt with jointly in the following pages.

When the ground is to be soon with seed coming in from outside, the regeneration felling, *i. e.* the felling, of which the immediate result is the production of the new crop, will be a clear one or only a partial one according as the young crop can dispense with, or requires, being nursed ; whereas, if the parent trees stand overhead, that felling must necessarily be partial, and the original crop can be entirely removed only when the new generation has been completely obtained. We thus have, broadly speaking, two principal modes of obtaining natural regeneration by seed, *viz.* (*a*) by means of clear fellings, when the original crop is required neither as parent nor nurse, and (*b*) by means of partial fellings, when the original crop is both parent and nurse, or at least nurse.

Now clear fellings may be made (i) over large areas of irregular shape, or (ii) in long narrow bands, or (iii) over very limited areas (forming gaps or wells in the forest), thus giving rise to three distinct methods of natural regeneration by seed, which we may term respectively the *method of clearings*, the *method of cleared lines* and the *well method.* Partial fellings, on the other hand, may (i) be made in a uniform manner over the entire area to be regenerated or (ii) they may observe a strict uniformity only over homogeneous portions (*groups*) of that area, each separate portion being treated

on its own merits, or (iii) they may be made uniformly over successive narrow strips into which the area may be divided, or (iv) they may merely remove a tree or two without any order from scattered points all over the area. This gives us four more methods of natural regeneration by seed, which may be designated respectively the *uniform method*, the *group method*, the *strip method*, and *jardinage*. In the first three of these methods the entire original crop ultimately disappears within a definite limited number of years, whereas in the last there is never any point of time when that crop can be said to have ceased to exist and to have been completely replaced by a new generation.

The various methods of natural regeneration by seed, as now explained, may be exhibited synoptically thus.—

NATURAL REGENERATION BY SEED

by means of

- *Clear fellings*
  - Made over large areas of irregular shape ... THE METHOD OF CLEARINGS ... 1
  - In long narrow strips ... ... THE METHOD OF CLEARED LINES ... 2
  - Forming mere gaps or wells in the forest ... THE WELL METHOD ... 3
- *Partial fellings*
  - Effected uniformly at each operation
    - Over the entire area to be regenerated. } THE UNIFORM METHOD ... 4
    - Only overthe component homogeneous groups of that area, each group being treated independently on its own merits. } THE GROUP METHOD 5
    - Successively over long narrow strips, into which the original area to be regenerated is divided. } THE STRIP METHOD 6
  - Effected without any uniformity whatsoever, a tree or two being removed from various scattered points all over the area in which new seedlings are desired. } JARDINAGE 7

SECTION I.

The method of clearings.

DESCRIPTION OF THE METHOD.—In this method, as already explained above, a large area of irregular contour is completely cleared and the regeneration is made to depend on seeds reaching every point of the ground from outside. The seeds may be brought in principally—

(i) *By the wind,* which will always act more or less effectively, and must be utilised in the fullest measure in every case. The extent to which it can be relied on will depend on its velocity, on its constancy both as regards direction and force, on its prevailing at the very time the seed ripens, on the position of the clearing with reference to it, and on the weight and shape, *i. e.*, the transportability, of the seed. Moreover the seed will be carried furthest if the wind blows down a slope.

(ii) *By the mere force of gravitation.* For this cause to be effective the coupe should be situated at the foot of, or on, a slope, with fertile trees standing above. If it is on the side of a hill, it is also necessary that the seed should find a lodgement on the slope and not continue to roll or slip downwards ; so that the steeper the gradients are, the rougher must be the hill side, or the smaller, lighter, flatter or otherwise clinging the seeds.

(iii) *By surface drainage.* Whenever heavy rain falls on saturated soil, seeds will always be washed down to lower levels by the surface drainage, and the quantity arrested in any place will depend. on the roughness of the surface of the ground due to unevenness of contour or an abundant covering of herbs and shrubs, on the size, weight and shape of the seeds, and on the quantity and velocity of the water flowing over it. If the soil has been hardened and stripped of all low vegetation by heavy grazing or fire, the seeds will mostly be washed away into the streams and hollows, especially if, like teak, they take any time to germinate. On hill sides ledges and projecting rock, boulders, &c, will catch numerous seeds and break the force of the descending water. Lastly, seeds carried into streams that spread out over wide areas, will be deposited in slack water and left high and dry when the flood waters subside into the regular channels, as happens on a large scale in respect of sissu and *Acacia Catechu* where Himalayan streams debouch into the plains, and of tamarisk and *Acacia arabica* in the Indus valley. Thus the sowing of any particular coupe by

means of surface drainage alone will generally depend on an indefinite extent of tree-covered ground standing above it in its own drainage area.

(iv) *The alternate ebb and flow of the tides.* This cause is effective on low coasts and in estuaries and deltas of rivers.

VALUE AND EMPLOYMENT OF THE METHOD.—We thus see that regeneration under the present system will depend principally (*a*) on the species in question, according to the abundance, regularity and certainty of their fructification, the size, weight, shape and easy germination of the seeds, and the hardihood, tenacity and rapid growth of the seedlings; (*b*) on the situation of the coupe, according to the extent of the area above it, from which it can be sown, and the number of trees thereon; (*c*) on the effectiveness and certainty of action of the causes influencing the transport of the seeds; and (*d*) on the comparative mildness of the climate and richness of the soil.

From the foregoing it is evident that this method of regeneration can be resorted to only in those very rare instances, in which all the prevailing conditions are exceptionally favourable. To judge whether they are so, is often beyond the power of the most experienced forester, and the risk run in its employment is so great that a slight error of judgment may result in the ruin of almost the entire area of the coupe, and it may take more than a quarter of a century for nature alone to effect the regeneration. And during all this time the soil is bound to run wild with weeds and otherwise deteriorate, and render subsequent resort to artificial methods an extremely expensive and difficult business. In any case, the soil must suffer from exposure, and the young seedlings, however hardy or tenacious they may be, from the complete absence of shelter, and, in nearly every instance, also from a heavy invasive growth of grass and other undesirable weeds. The frequently flooded islands and low ground in the deltas of our great rivers, the *chaors* and *kachas* of the Indus, the low islands of *Acacia Catechu* and *Zizyphus* at the base of the Himalayas, the easier slopes occupied by *Pinus longifolia*, &c. may offer occasions for employing this method. But before attempting to generalize it in any given locality, careful and cautious experiments must be made to place its efficacy beyond all doubt and independent of all contingencies.

SECTION II.

The method of cleared lines.

DESCRIPTION OF THE METHOD.—In this method long narrow belts of uniform width are completely cleared through the crop to be regenerated and the trees standing along either edge are expected to sow them. The width of the cleared lines is generally limited to the average height of the forest through which they are cut, so that the seeds have to be carried only a very few feet either way in order to reach the middle and, provided seed is produced, the complete sowing of the ground at any rate is assured.

On level ground the lines should run at right angles to the direction of dangerous winds. In hilly country, however, considerations of quite a different nature must determine the direction of the lines. When the gradients are moderate and there is no danger of the cleared lines degenerating into watercourses or of the young growth on them being injured by the slow glacier-like downward movement of lying snow, it is advisable to make them follow lines of steepest descent, thereby securing the following advantages :—(1) the trees, as they are felled, will not have to come crashing down the hill side through standing forest that is to be preserved ; (2) as most of the wood and timber will slip down to the lowest point of the slope, *i.e.*, into the valley below, their conversion, and particularly their export, will be singularly facilitated ; (3) the downward rush of the trees and logs will prepare the ground for the future sowing by destroying all injurious undergrowth, loosening the soil, and pulverising and mixing up with it any overlying accumulation of half-decomposed leaves and other vegetable *debris*, which would otherwise be a real obstacle to regeneration. But if there is danger in following lines of steepest descent, the cleared lines must obviously run more or less horizontally ; and in that case, they ought to succeed each other from the top downwards, so that the new generation may never have trees coming down crashing through it; and an intact belt of forest should be left highest of all in order to sow successively all the clearings made below. This topmost parent belt itself must be constantly kept up, and can, therefore, be regenerated only by the jardinage method; for a long series of years its presence is necessary as a protection for the young generations lower down the slope, and its maintenance thereafter is indispensable for the resowing of the highest cleared line when its turn for regeneration comes round again.

Moreover its exposed situation near the ridge will nearly always render any other mode of natural regeneration impossible.

On level ground the produce of the coupe should, as far as possible, be taken out by the cleared line itself, in order that the traffic may loosen the soil, break and crush down injurious weeds, comminute and force into the mineral soil the top layer of undecomposed vegetable *débris*, and press fallen seed into the ground. Grubbing out the trees, if the price of the extra wood obtained at least covers cost of extraction and the requisite labour is available, would be a further powerful help towards preparing the soil for successful sowing.

The coupes need not succeed each other on the ground year after year in the respective order of their dates, but at intervals of years varying with the readiness and degree of certainty of reproduction and the favourable nature of the soil, climate and covering of bushes and weeds. As a rule, the forest on both sides of a cleared line should be left intact as long as the reproduction on it is not assured. Hence in unfavourable localities the coupes will be situated in as many separate groups as there are years in the interval elapsing between the clearing of one line and the one immediately adjoining it.

VALUE AND EMPLOYMENT OF THE METHOD.—The advantages the method offers are numerous. Rain falls directly on the ground and on the young seedlings; heavy dews can form and direct sunlight and a genial warmth are admitted without risk of frost or excessive insolation; air circulates freely without any entrance being given to dangerous winds; the roots of the young plants are not prevented from extending themselves and drawing nourishment from the soil by the more extensive and more powerful root-apparatus of large trees standing in their midst; the felling and export operations need never interfere with the new generation, except in so far as they may injure advance growth, which indeed it is impossible to leave unharmed whatever method of felling we may adopt; the felling and export operations themselves afford the very best preparation for sowing that can be given to the soil, and save resort to those special costly measures which are nearly always an indispensable accompaniment to other methods of natural regeneration by seed; and, lastly, the almost mathematical regularity and extreme simplicity of the work of regeneration demand but little skill and experience on the part of the forester to conduct it to a successful issue. The result of all these advantages is that great

economy is secured and the chances and fatal consequences of mistakes are minimised, and the new crop becomes established earlier than by any other method of natural regeneration by seed; but for this it is necessary that the species to be reproduced should be at least fairly hardy and tenacious and fructify abundantly nearly every year, and that their seeds should germinate readily. If there is already some advance growth on the ground, the chances of success are then completely assured. The only disadvantage inherent in the method is that in a mixed forest undesirable species may gain an undue predominance in the new crop. Hence the method of cleared lines is suited only for employment in pure or almost pure forests, where the principal species in each case is pre-eminently gregarious. But as such species comprise sal, *Acacia Catechu*, *Hardwickia binata*, *Pinus longifolia*, *Mesua ferrea*, the various species of *Anogeissus*, *Pterocarpus Marsupium*, &c., the method is evidently capable of very extensive generalisation.

SECTION III.

The well method.

In this method small clearings, up to half an acre or so in extent, are made here and there throughout the crop to be regenerated. Such openings in the forest often occur from purely natural causes—damage by storms, ravages of elephants, &c. In respect of regeneration alone, if the trees standing along the edges of the *wells* are fertile and belong mostly to desirable species, the conditions for success are still more favourable here than in the method of cleared lines, since there is effective shelter on every side, and whichever way the wind blows or the ground slopes, the area must get completely sown. But, on the other hand, in regard to convenience and economy of conversion and export and the restriction of damage caused by those operations, it is so far inferior to that method, that its employment as a system must be confined to those forests in which, owing to the difficulty of securing natural regeneration, either because of the steepness of the slopes or the extreme nature of the soil and climate, only small and scattered clearings can be made with safety. Like the method of cleared lines the well method can yield successful results only with species that seed abundantly, reproduce themselves freely, grow gregariously, and do not mind a certain amount of smothering in the midst of a rank growth of weeds. Hence, as the main means of regeneration, the well method will always be of only exceptional application, but

as a complement to other systems, it will often be employed with the happiest results. Thus, for instance, a forest may be so badly damaged at certain points that the best thing to do would be to utilise at once all the injured stock and thereupon forthwith undertake regeneration at those points; and so on.

SECTION. IV.

The uniform method.

In this method each operation of the regeneration series is carried out more or less uniformly and simultaneously over the whole of a crop. The result of the entire series, if successful, is that a young generation comes up in a uniform manner over the entire area and also grows up in the same way, so that at all times and every where it presents a general uniformity of age, height, density and composition. Hence the name given in this manual to the method in question.

The practical value of the method and to what extent the principles on which it is based can be realised in India, will be examined in its proper place afterwards. For the present we will, in order to describe the method, assume that all prevailing conditions are favourable for the attainment of these uniform results and that the crop has grown up in a complete state from the beginning.

The production and establishment of a new generation under the original or parent crop is possible only under the following three conditions:—

(i) The parent crop must contain a sufficient number of fertile trees of each of the species to be propagated, to completely sow the ground in the respective proportions desired of the several species.

(ii) The soil must be in a fit state to offer a good germination bed to the seeds and to nourish and maintain in a healthy and vigorous state the young plants resulting therefrom.

(iii) The seedlings must, at every stage of their development and in proportion to their size and vigour, receive sufficient light above ground and growing room inside the soil away from close contact with the roots of old trees having the same requirements.

All these conditions must be obtained, as far as possible, as the direct result of the regeneration fellings, and the success of the entire series must be measured by the smallness of the amount of extraneous help that it has been necessary to give.

The whole process of regeneration naturally divides itself into three distinct stages as follows:—

I. *The preparatory stage,* during which the soil is prepared to receive the seed, and the parent trees to stand isolation and to bear a large quantity of good seed;

II. *The sowing stage,* the sequel of which is the sowing of the ground and the production of a sufficient number of seedlings; and

III. *The after stage,* during which the growing seedlings are gradually admitted to an increasing share of enjoyment of light, dew and other beneficent atmospheric influences, until at last the entire original crop is removed.

And we have thus three distinct classes of regeneration fellings:—(*a*) the PREPARATORY FELLINGS, (*b*) the SEED FELLING and (*c*) the AFTER-FELLINGS.

ARTICLE 1.

THE PREPARATORY FELLINGS.

I. Object of the preparatory fellings.

In a regular crop sprung up from seed and growing under normal conditions, the trees, up to the time they reach the age of fertility, consist of a long thin bole surmounted by a small tuft of branches, by no means rich in foliage, for a crown. In other words, they are then in the worst possible condition to produce good or abundant seed; and indeed, in the case of most species, even the most shade-enduring, until the trees are isolated and allowed to extend their crowns, they either could not bear any seed at all or would furnish a few barren or weak ones. Then again, unless they are gradually thinned out before being sufficiently isolated to bear a good crop of seed, the moment they ceased to support one another, their fragile stems would either bend or break under the force of the wind and the pressure of the crown, weighted or not with rain or snow, and many of the trees, owing to their very limited root-apparatus, would even be uprooted. Besides this, the sudden exposure would kill many of the trees by calling forth, in the subaërial portions at the expense of the reserve matter, an outburst of activity, with which the roots could not keep pace, so that when this reserve matter was exhausted, the limited and weak root-apparatus could not meet the demands of the overgrown crown, the result being starvation as well as over-transpiration.

The object of the preparatory fellings with respect to the parent crop is hence to gradually give the trees increasing room both in the air and in the soil, and thus to allow the crown and the roots to expand in a proportionate manner and the bole to acquire sufficient strength to resist breaking when the trees are isolated.

As regards the soil, under a dense canopy of trees it will, in the Himalayas generally, and in evergreen forests invariably, be found covered with a thick layer of fibrous or charred humus and unreduced vegetable *débris*. Seedlings produced on such a surface would either be poisoned or, being unable to get down deep enough into the true mineral soil below, would wither up when the loose mass in question had lost all its surplus hygroscopic moisture in the dry season. The opening out of the leaf-canopy in the preparatory fellings, by admitting heat and a free circulation of air under the forest, hastens the reduction and decomposition of this obnoxious covering. But other special measures have also to be undertaken, as an integral part of the preparatory operations, to further this natural process.

II. When to begin the preparatoty fellings.

The time to begin the preparatory fellings in any given case will depend—

(i) *On the component species.* Different species grow up with different degrees of rapidity, reach different statures which they attain at different ages, enjoy different terms of longevity, become fertile at different ages, require different degrees of insolation and different periods of release from an overcrowded state in order to be able to acquire a sufficient spread of crown and come into full bearing, and so on. Thus trees, which attain the best marketable dimensions at an early age, or which become fully fertile late, or which naturally grow crowded together, and so on, require to be prepared from an early age.

In a mixed forest, the time to begin the fellings will be determined entirely by the exigencies of the principal species, and if there are more than one such species, by the exigencies of that one among them, which becomes fertile last of all, or which, being the slowest grower or the most shade-avoiding, requires to be given a start over its fellows (See pp. 126-7, II and III).

(ii) *On the soil,* which will obviously influence the rapidity and vigour of growth of the trees, their longevity, their bearing age, their habit, their requirements in respect of light, and their fruitfulness and the quality of their seed at different ages. For

instance, in favourable soils the preparatory fellings will generally be delayed. Then again, the condition of the soil as a seed-bed will also be an important factor for consideration. Its suitability will depend not only on its inherent properties, such as its stiffness, hardness, hygroscopicity, richness, &c., but also, to a very great extent, on the condition of its surface. The stiffer or harder or drier or poorer the soil, the thicker the undecomposed layer of dead leaves covering it, or the denser the growth of weeds and brushwood on it, the longer will it take to get ready for sowing and the earlier must the preparation be begun.

(iii) *On the climate and locality.* In hot sunny localities the leaf-canopy is generally naturally open and the trees are seldom so narrow-crowned as to require much encouragement to become prolific seed-bearers; hence there preparatory fellings may, and often must, be made comparatively late. On cool or moist aspects, in temperate climates, under clouded skies, &c., on the other hand, the earlier those fellings are undertaken, the better.

(iv) *On the actual condition of the crop, i. e.,* its density and the age, height, soundness, vigour and shape of the component trees. For instance, the denser the crop, the younger or lankier or weaker or more unhealthy the trees, the earlier must preparation for regeneration commence. So also in an old crop, in which the trees have already begun to contract their crowns, there is no room for delay.

As a rule, the preparatory fellings must not be taken in hand before the stems of the principal species have nearly attained the lowest diameter at which they may be felled solely with reference to the market and independently of cultural requirements; and they must give the future parent trees sufficient time to spread out their crowns and come into full bearing by the time the seed felling falls due. They will thus precede this felling by an interval which may vary from 2 to 20 or even 30 years, but the more usual period will be from 10 to 15 years.

III. Number of the preparatory fellings.

The number of times the preparatory fellings should be made will depend—

(i) *On the component species.* The more liable the trees are to be broken or blown or bent down, or to suffer from sunstroke or too sudden isolation, the more gradually and cautiously must the leaf-canopy be opened out, and hence the more frequent must be the fellings. So again, the more rapidly the crowns expand and

completely reform the broken leaf-canopy, the oftener must it be reopened. In a mixed forest, both because the leaf-canopy closes up again earlier and certain species often require to be specially favoured, the preparatory fellings will generally be more numerous than in pure forest.

(ii) *On the soil.* The richer the soil is, the greater will be the danger of a strong growth of weeds, and hence the more cautious and, therefore, more frequent must be the fellings. So also, if the soil is favourable to the rapid growth of the trees.

(iii) *On the climate and locality.* The caution to be observed and, therefore, the frequency of the fellings will of course be in proportion to the extremeness of the climatic factors. A very favourable (forcing) as well as very unfavourable climate and locality will require the fellings to follow each other at short intervals.

(iv) *On the actual density of the crop.* The closer the trees stand together, the more likely are they to be thin and lanky, weak-rooted and wanting in vigour, and hence the necessity of frequent light operations.

(v) *On the predominant age of the crop.* The more advanced the age of the majority of the trees beyond that of first fertility, the greater, as a rule, will be the necessity of obtaining the desired results in a limited time, and hence also for often repeating the felling.

(vi) *On the condition of the crop.* The more damaged or unsound the trees, the more frequently must the woodcutter be admitted.

(vii) *On the necessity of obtaining the desired results as quickly as possible.* The crop to come under regeneration may be very young and hence require special forcing to induce early and abundant fertility. So also, if the position of the crop in the forest necessitates its regeneration without delay. In either case, the only possible mode of attaining the end sought, without risking the safety of the crop, is to thin it out frequently, but each time lightly.

(viii) *On the question whether a seed felling can be made every year or only at intervals of several years.* In the latter case, the preparatory fellings will usually have to contribute, to an appreciable extent, towards making up the annual yield during the interval between two seed fellings; and hence, in order to spread the produce of the preparatory coupes over as many indivi-

dual years as possible, the fellings should be light and come round again frequently.

In extreme cases a single preparatory felling may suffice, or none at all may be necessary; but usually the number of these will vary from two to four, repeated at intervals of from 4 to 6 years.

IV. What to remove in the preparatory fellings.

The main point to bear in mind is never completely to isolate the trees, but to make numerous gaps in the leaf-canopy, larger or smaller according to the prevailing conditions of growth, but always small enough to enable them to close up within a few years, before the soil can suffer from exposure. In making these gaps it is neither the oldest nor the youngest, nor yet the weakest or the most vigorous that should be removed, but those which differ most from the predominant age or size-class. We must endeavour to produce a crop composed of trees of more or less one and the same age, size and vigour, and as many of which as possible shall come into full bearing when the seed felling falls due. As regards species, all undesirable ones should be got rid of or reduced to the minimum compatible with the required fulness of the leaf-canopy. After leaving enough seedbearers of each of the better species to reproduce themselves in sufficient abundance in the new crop, the surplus should consist of promising individuals of those most in demand.

Hence in making the preparatory fellings, the following principles should be observed :—

(i) Wherever a gap already exists, nothing, as a rule, should be felled.

(iii) A sufficient number of individuals of every desirable species present should, as far as it is feasible, be left standing to assure its reproduction in the required proportion in the future crop.

This proportion is not necessarily the same as what should exist at the end of the rotation, when obviously those possessing the highest market value should be most largely represented; but provided the crop contains a sufficient number of seedlings of these species to enable them to secure the desired majority afterwards, the remaining seedlings should belong preferentially to those species which are most valuable from a purely cultural point of view. Of course one and the same species may both command the highest market value and lend itself to the most profitable

growth of the crop, as, for instance, sal compared with nearly all its possible companions, and deodar compared with the firs. In the case of teak, its soil-improving companions should form the majority of the young seedling crop, so long as there is enough of it present to give as many stems as possible, up to about 80 per acre, when the crop becomes ripe for the axe.

(iii) Subject to Principle (ii), as many stems as possible of the more valuable species should be preserved, each in proportion to its selling price and the demand for it.

(iv) Of two equally promising individuals of the same species, that one should be preserved which belongs to the predominant age or size-class, unless the difference between them is very slight, in which case the larger of the two will of course be kept.

(v) All trees with low spreading crowns should, if possible, be got rid of. But if their removal creates too large a gap to close up within a reasonable period, or if the neighbouring trees are too young or too little developed to become fertile in proper time, they must be spared, the undue spread and lowness of their crowns being corrected by judicious lopping and pruning.

With one and the same density of growth, the ground is better lit in proportion to the height of the mass of foliage above it. A low crown generally means also a deep crown, and a high crown one that possesses little depth and lets abundant light filter in through it. Moreover a deep and spreading crown has, in the soil below, its counterpart in a deep and spreading mass of roots, which, under the most favourable circumstances, must oppose the growth and establishment of seedlings within the area they occupy.

(vi) The taller the crop and the more raised above the ground the leaf-canopy, the smaller must be the gaps made; and *vice versâ*. The reason is evident from what has just been said under (v). Moreover under a high leaf-canopy, the light is more uniformly distributed over the ground below, whereas under a low cover there are bright lights intermixed with deep shadows.

(vii) The younger the trees are, the larger must be the openings made in the leaf-canopy, and *vice versâ*; firstly, because younger trees spread out more rapidly, and, secondly, because the younger the trees are, the more forcing do they require in order to attain early and abundant fertility.

(viii) In a mixed, as opposed to a pure, forest the fellings may usually be heavier, since in a mixed forest the number of stems

is generally larger, gaps are more quickly filled up, the fertility of the soil greater, and accidents less dangerous (See pp. 108-114 *passim.*)

(ix) All trees that cannot live or at least remain sound up to the first few years following the seed felling, should, if their removal does not create too large a gap and they are not absolutely required as seed-bearers, be taken out.

(x) Trees with heritable defects should, as far as possible, be got rid of.

(xi) If the trees to be removed are not to be grubbed out, or belong to species that throw up root-suckers, the fellings should not be so heavy as to encourage the production of stool-shoots and root-suckers.

(xii) In temperate and in tropical evergreen forests, where heavy brushwood at once springs up on the admission of only a moderate amount of light, the fellings should be very cautious.

V. Selection and marking of the trees to be felled.

As the number of trees to be preserved must always far exceed those to be felled or lopped, it is obvious that, in the interests of economy both of time and money, it is these latter which should be marked.

The best time for selecting the trees to be marked is when the entire crop is in full leaf. It is then that the various species are most easily recognised, and it is only then that the soundness, vigour and spread of each individual tree can be correctly appreciated.

The marking party should work in successive sweeps backwards and forwards, beginning with the most convenient edge of the coupe. Much time will be saved and distraction of attention from the work of selecting the trees avoided, by previously marking out the sweeps by means of straight parallel lines with the aid of surveying instruments or even simply of flags. The lines may be defined, for easy recognition, by means of blazes or splashes of whitewash on trees sufficiently close togather or of splashes on the ground or herbage and bushes covering the ground. Each sweep should be just wide enough for the officer conducting the work of selection, as he moves along the middle, to have an unobstructed view of the trees on either side of himself; so that the width in any case will vary with the class of forest concerned. To assist that officer in keeping his bearings two men should walk on a few paces ahead, one along each edge of the sweep.

The selecting officer's attention should be directed first of all to all suppressed, unhealthy and overtopping trees. If, after marking these, he finds that the growth still remains too close, he should take, from among the remaining trees, those individuals of the less valuable species, and even of the more valuable ones, which ought to come down in accordance with the principles explained in the immediately forgeoing sub-article.

A different mode of marking should show which trees are to be felled by the base, which are to be only lopped, and which are to be grubbed up by the roots. The first class should always be marked in two places, one as near the ground as possible, the other at about breast-height, so that there may always be an indicative mark left on the stump, wherewith to check the wood-cutters. It is always advisable to mark the trees uniformly on the side on which the sweeps follow each other, so that the marks may be seen directly from the next sweep taken up. To facilitate the recognition of the selected trees, both for the marking party and for the wood-cutters, a ring or splashes of white-wash may also be put on those trees.

It goes without saying that, as the trees are selected and marked, they should be measured and their species and size (girth or diameter, and also height, if necessary) recorded.

VI. Execution of the preparatory fellings.

As by far the greater portion of the stock is spared, and the trees to be left stand close together, too many precautions cannot be taken to reduce the amount of damage inevitable in the felling and export operations. The fall of the trees should be directed with care and judgment, and, if necessary and practicable, the larger and heavier crowned trees should be lopped, in order to diminish the momentum with which they come down and to restrict the area over which they can do damage.

It is always advisable, when the state of the market permits of it and the safety of the ground is not thereby threatened, to grub out the trees instead of merely felling them by the base. The price of the extra wood thus obtained may not only compensate for the additional expenditure incurred, but also even cover a great part, if not the whole, of the working expenses of the preparatory operations generally. But the success of the operation is not to be measured only by the money returns it directly yields, but also,

thanks to the way in which it loosens and breaks up the soil, by the great help it gives to natural regeneration, saving, it may be, a final compulsory recourse to expensive artificial methods. Instead of first felling a tree in the ordinary way and then grubbing out the stump and principal roots, it is best to at once expose and undermine the main roots and bring the entire tree down by cutting these through.

Where carts may be admitted without injury to the standing crop, the trees may be converted where they fall and removed only after conversion; otherwise, after being lopped and rough-dressed, they should be carried out without delay to the nearest road side.

Pari passu with the felling and conversion operations, all low brushwood should be removed with the help of grubbing or hoe-axes (Figs. 14-17). If the ground is covered with a thick layer of undecomposed or half-decomposed dead leaves, cattle, or, better still, swine should be admitted (see. p. 253 para. 2), or the débris should be crushed and mixed up with the soil with the aid of drags (Fig. 41), hoe axes (Fig. 16 and 17), pickforks (Fig. 40) or with hoes similar to those represented in Figs. 86 and 87. The use of cattle and swine is of course out of the question on steep hill sides, on loose slopes, and in marshy land. Bad swamps should if practicable at a reasonable outlay, be drained.

ARTICLE 2.

THE SEED FELLING.

I. Object of the felling.

If the preparatory operations have been judiciously carried out, there will always be a more or less considerable reproduction on the ground when the time for the seed felling arrives, and that felling will then really be nothing more than a supplementary operation to complete the sowing so happily begun during the preparatory stage. But we will still continue the supposition of ideal uniformity of growth, with which we started in undertaking the description of the present method of natural regeneration. And so it will be permissible to assume that the preparatory stage has resulted in the formation of a crop composed of trees that are about to come into full bearing, and in the conversion of the soil into a more or less good seed-bed. Now arises the necessity of finally preparing the soil, which cannot but have deteriorated since the last preparatory felling, and of opening out the leaf-canopy

rather more than before, in order to admit enough light to keep the future seedlings alive and vigorous during the first two or three years, without however allowing a mass of weeds and stool-shoots and root-suckers to spring up and injurious atmospheric influences to enter, or forming breeding a ground for destructive insects. This end it is the object of the seed felling to accomplish.

But the seed felling may sometimes be required to fulfil also another object. Owing to the time allowed for preparation being too short, or for any other reason, the crop may be too dense for an abundant flowering to result in a proportionately abundant seeding. In that case, the seed felling, by opening out the leaf-canopy, serves to encourage fructification.

II. When to make the seed felling.

The great rule to follow is to allow as short an interval as possible to elapse between the conclusion of the seed felling and the appearance of the new crop, so that in the mean-while the soil may not have time to deteriorate or the leaf-canopy to become too close again. Hence the seed felling should be made only when a good crop of seed has already formed or is at least indicated with certainty.

The seed of some species requires many months before it can germinate at the commencement of the next season of vegetation; *e. g.* teak, deodar, *Pinus longifolia, Quercus incana, Hardwickia binata, Terminalia tomentosa, Acacia modesta, Pterocarpus Marsupium,* the various *Anogeissus, &c.* In regard to them the seed felling should be made only after the seed has ripened, and, if the seed is shed early enough, only after it has reached the ground. In the former case the soil is in the highest state of preparation when the seed falls, in the latter the further great advantage is gained that the seeds get pressed into the soil by the felling and export operations; and in either case, no mistake can be made as to the sufficiency and quality of the seeds, and every tree contributes its full quota towards the sowing of the ground.

When there is not sufficient time to wait until the seeds are at least ripe, as in the case of sal, *Quercus semecarpifolia* and *dilatata, Mesua ferrea,* eng, &c., the only indication left to follow is the flowering, and, in some instances, even the mere appearance of the inflorescence buds, which may, after a little practice, be readily recognised from purely foliage buds by their larger size and greater fulness. As fructification may fail owing to fires or to attacks of insects or to frost or adverse weather influences, the

best promise of a good seed-crop may sometimes prove deceptive. But ordinarily expectation will not be entirely disappointed, especially if the process of fructification is a rapid one and occurs at a favourable time of the year, as in the case of most of the species just enumerated.

When the object of opening out the leaf-canopy is, besides admitting light for the benefit of the future seedlings, also to help fructification, then the seed felling must perforce be made as soon as the inflorescence buds make their appearance.

Some species seed abundantly almost every year, although more so in some years than in others, *e. g.* teak, sal, *Acacia arabica* and *Catechu, &c.* Others, although they seldom fail to produce some seed annually, seed profusely at regular or irregular intervals of several years, *e. g. Pinus longifolia,* deodar, &c.; while others again seed gregariously and abundantly only after the lapse of several years, with no seeding, or next to none, during the intervening period, *e. g. Hardwickia binata,* the bamboos, &c. It is a fact worthy of special record that, even in the case of the first group of species here referred to, seeds produced in years of profusion not only possess more vitality and produce stronger plants, but germinate more freely and in much larger proportion than those produced in intermediate years. This difference is most conspicuous in the case of the third class of species mentioned above. Hence, in every case without exception, the absolute necessity of limiting the seed felling to the years of profuse gregarious fructification.

In conclusion, it is necessary to add that, however careful and cautious one may be in selecting the year for making the seed felling, mistakes may sometimes be made, or at least expectations may not be completely fulfilled, in which case a second seed-felling may have to be made on the very next favourable occasion that offers.

III. Severity of the seed felling.

The amount of light admissible inside a seed coupe must satisfy the aggregate requirements in each case, and will hence be as various as those requirements. It will depend —

(i) *On the species to be reproduced.* According to their species the trees will require different degrees of isolation to be able to bear a plentiful crop of good seed, and the seedlings different degrees of illumination not only to be able to grow, but even simply to live in a healthy condition.

Some species suffer more or less than others from immediate contact with weeds and brushwood, the abundance of which in each case will mainly be proportionate to the amount of light reaching the ground. Then again, the leaf canopy must be more or less close, according to the component species, to prevent a regrowth from the stools and roots of the trees cut. In mixed forest the amount of light admitted into the coupe will be regulated especially in the interests of those species whose propagation is most largely desired, or of some one or more of the principal or auxiliary ones the reproduction of which is peculiarly difficult. If an advance growth of any of the species has come up as a result of the preparatory fellings, the seed felling will obviously be more adapted to the requirements of the rest in proportion to the sufficiency of that advance growth and to the importance of the latter class of species or the difficulty their regeneration presents.

(ii) *On the age and condition of the parent crop.* The younger or more vigorous the component trees are, the more speedily will they expand their crowns and narrow or close up the openings made in the leaf-canopy by the seed felling, and hence the more open must be the felling. Then again, it must be remembered that with the same density of the leaf-canopy, light is more effective and there is more room in the soil under lofty than under low, deep crowns.

(iii) *On the nature of the soil and locality.* Due consideration must be given to the brightness or heating power of the sun, the clearness and dryness of the atmosphere, the character of the aspect, the severity or mildness or absence of frosts, the violence, constancy, direction and harmfulness of dangerous winds, the frequency and abundance or fitfulness and scarcity of rain, &c. Some soils are more liable to drought than others, or to be overrun with rank weeds and brushwood, or to be infested with insects, and so on. In respect of gradient it must not be forgotten that the steeper a slope is, the more side light can enter the forest through one and the same density of leaf-canopy, and the greater is the danger of erosion.

(iv) *The effectiveness of the preparatory operations.* In proportion to the effectiveness of the preparatory operations will be the certainty and completeness of the sowing of the ground, the suitability of the soil as a seed-bed and a nourishing medium for the young seedlings produced, and the fitness of the parent trees for the office of nurse and for maintaining the fertility of the soil.

In addition to this, a considerable amount of advance growth may come up during the preparatory work and not only justify but even call for a free style of felling.

To determine the degree of severity of the seed felling in any given case is thus a work requiring great experience, a thorough knowledge of prevailing conditions and a nice discrimination. But for the benefit of the unpractised student we may lay down the following general rules, which embrace the cases of most frequent occurrence.

A. The felling must be *dark*—

(1) On all naturally dry soils;

(2) On all very free soils.

(3) On all rich soils that are liable to be overrun with a rank growth of weeds and brushwood.

(4) On very poor soils.

(5) On all steep slopes.

(6) On all southerly, and, in these parts of India which are exposed to hot winds, also on westerly aspects.

(7) In all localities in which dry, scorching or very cold or very violent winds blow.

(8) In all frosty places.

(9) Wherever insects in the soil are likely to abound.

(10) In crops composed of superficially-rooted trees.

(11) In all places in the Himalayas in which vegetation starts anew very early in spring, when frosts can still occur.

(12) Wherever the new generation is delicate or slow-growing or wanting in tenacity in struggling with neighbouring plants of inferior species.

(13) In all old crops, in which the trees have already begun to contract their crowns or have at least ceased to develop them any further.

(14) In all crops composed mainly of trees with long thin boles and narrow crowns.

(15) In all cases in which the production of a good crop of seed is uncertain.

(16) In mixed forest, in all cases in which the seeds of the principal species germinate with difficulty and the number of the resulting seedlings is, therefore, not necessarily in proportion to the abundance of seed produced.

(17) In mixed forest, when a *bright* felling would give an undesirable predominance to certain species at the expense of the rest.

B. On the other hand, a *bright* felling can be made, only provided no single one of the preceding seventeen conditions exists. But there are three exceptions to this rule, in each of which the seed felling *must* be bright—

(1) When the seedlings to be produced can survive only under the influence of more or less direct sunlight.

(2) In places inclined to be swampy.

(3) In a crop composed of trees with very low crowns.

The darkest coupe we can have is one in which the crowns touch each other, completely or very nearly so, along their edges; and the brightest coupe would be one in which no more trees were preserved than would just suffice to sow the ground to the desired extent, the seedlings being able to do without nurses and the soil requiring no protection.

In a mixed forest composed of species possessing very different requirements, the severity of the seed felling at any particular point will be specially suited for the species whose reproduction is actually required there. And it is hence possible for one and the same coupe to be dark at certain points and bright elsewhere.

The two terms *dark* and *bright*, used now for the first time in connection with the density of the stock in a coupe, are not to be understood in any technical sense as signifying each some definite intensity of solar illumination. No more definite idea is intended to be conveyed by those terms than if, in speaking of a room, we said that it was bright or dark. There are different degrees of brightness just as there are different degrees of darkness, and one dark coupe may be darker than another, just as a third coupe that is bright may be brighter than a fourth which itself may also be classed as bright.

The openness or closeness of a coupe has often been measured either (*a*) by the intervals between the crowns of the trees, or (*b*) by the number of stems left, or (*c*) by the aggregate area of all the stem sections, or (*d*) by the average interval between the stems, or (*e*) the ratio between the average interval between the stems and the average girth of all the stems, or (*f*) by the quantity of produce removed, or (*g*) by the quantity of material left standing. It must be admitted that none of these various bases of measurement employed singly can yield any trustworthy results, since the openness or closeness of a crop, as regards the amount of effective light reaching the ground under it, is necessarily a treble function of the number of stems composing it, the spread,

depth and spacing of the crowns, and the length of bole of the trees. If the crop were originally a complete one and its contents were accurately known, then the last two bases of measurement would of course, for all practical purposes, serve as a sufficiently accurate standard to adopt.

IV. What to remove in the seed felling.

If the process of fructification has not to be assisted, then, provided their removal does not open out the crop too much or deprive some desirable species of its necessary complement of seed-bearers, the following trees should be taken out :—

(i) *All low-crowned trees,* if any still remain in spite of the preparatory fellings.

(ii) *All large-crowned trees,* which, besides being bad nurses and monopolising the soil in which their roots ramify, must, if felled afterwards, do considerable and wide-spread damage among the young growth.

(iii) *All suppressed trees,* which, without being able to come to any good themselves, only uselessly occupy soil that would much more profitably be left to the roots of the new seedlings.

(iv) *All trees that tower above the rest.* Such trees, for any large increments they may make individually, would keep back their very much more numerous neighbours and thereby prevent a much larger possible aggregate increment.

(v) *All thin lanky trees,* which are likely to get broken or at least bent down when isolated.

(vi) *All unhealthy unsound trees, and those in full decay.* These trees ought obviously to be utilised before they become completely useless and also in order to give room to growing trees.

(vii) *All trees with heritable defects,* which detract from the usefulness and market value of their timber.

(viii) *The older weakly trees* from among overcrowded groups.

(ix) *Trees of inferior species* adjoining sound and promising individuals of more valuable kinds and not required either in the interests of regeneration or of the fertility of the soil. If the more valuable species are unable to protect the soil, a sufficient number of individuals of inferior soil-improving species must of-course be preserved. If an advance growth of any of the inferior species has come up any where, then, save the exception just indicated, there ought to be no hesitation in ridding the parent crop at such points of individuals of those species.

(x) *Seed-bearing trees of inferior species*, which threaten to obstruct the more difficult or tardy reproduction of the more valuable kinds.

If in addition to the necessity of admitting enough sunlight for the future crop of seedlings, the seed felling is required also to help the formation of seed, then, if necessary, besides observing all the ten conditions just enumerated, the leaf-canopy shonld be further opened out round each of the future parent trees that is in want of such help. But usually the carrying out of the fellings in accordance with those ten principles alone will suffice to secure the desired object.

V. Selection and marking of the trees to be felled.

Bearing in mind the principles set forth in the two preceding sub-articles we may proceed to select and mark the trees in the same manner as that recommended for preparatory fellings (p. 370). Neverthless, as the seed felling necessarily makes larger and more numerous gaps in the leaf-canopy, there is need for much greater care and circumspection in the present case. It is thus often advisable to do the work in two separate operations, marking in the first those trees about the removal of which there can be no question, and then going over the ground again to choose the rest and complete the operation. But the best plan is not to actually go over the same ground a second time, but to narrow the sweeps so that from the middle of any sweep the trees may be easily examined as far as the middle of the sweep on either side, and the marking may thus go on simultaneously over the whole width of one sweep and the near half-width of the two adjoining sweeps. In this way every tree comes under review twice from two opposite standpoints and the chances of an erroneous judgment are greatly minimised. On the first examination, trees, the removal of which is urgent, should be at once blazed and hammered, the doubtful ones being only blazed outside the quick. On the second examination, if the choice still falls on one of the superficially blazed trees, independently of any circumstances which led to its being selected in the first instance, the blaze should be continued into the wood and forthwith hammered. Obviously the wood-cutter will have no concern with the trees which bear simply a blaze.

VI. Execution of the seed felling.

The lines of work here are similar to those to follow in the preparatory fellings, but the leaf-canopy being more opened out in this case, greater care should be exercised in directing the

fall of the trees, and there is less necessity for lopping the branches of spreading trees. Moreover, for the same reason, and also because the sowing of the ground is either more or less accomplished or is imminent, the soil must be prepared in a more complete manner. All weeds and brushwood that can be pulled up by the roots, should be so extracted, otherwise they should be grubbed out by the crown of the roots with grubbing or hoe axes (Fig. 14, 15, 16 and 17). The methods of preparing the soil described on p. 252 under (I) and on the following page under (II) are both applicable here, and if circumstances require or permit of it, the soil may be worked up with powerful ploughs. When the noxious undergrowth or dead vegetable covering is extremely thick and abundant, it will suffice, in order to reduce expenditure within reasonable limits, to prepare the soil in regular lines of square patches or plots of from 4 to 12 feet side and numbering from 80 to 200 to the acre.

VII. Repetition of the seed felling.

It may happen that the expectation of an abundant crop of good seed has not been realised, or that the seeds have been destroyed, or that, although the seeds have germinated, the seedlings have died off wholesale; under such circumstances a second seed felling must be made at the next general fructification. Or it may happen that the seed felling has designedly been made cautiously in order to provide against possible accidents during fructification, and that it is then found that the seeding has been successful; here a supplementary operation is obviously required to complete the original imperfectly-made seed felling. In either case, the principles to be followed are the same as those laid down in the preceding sub-articles.

ARTICLE 3.

THE AFTER-FELLINGS.

I. Object of the after-fellings.

The object of these fellings is to give to the new seedling crop, in proportion to its increasing requirements growing room in the soil, and to admit it to the beneficial influence of light primarily and of warmth dew and direct rain secondarily, without ever opening out the leaf-canopy to such an extent as to expose the seedlings to be killed or injured by drought, frost, excessive insolation, hail, movements of snow, storms, heavy rain or hot or cold winds, or be devoured by insects or be choked up by a strong dense growth of weeds, brushwood, and coppice shoots.

II. When to begin the after-fellings.

When these fellings should commence in any particular place will, for India, with its vast extent, great range of altitude, every variety of climate and enormous number of tree-species, be at all times an extremely difficult question to answer. In the present very limited state of our knowledge *à fortiori*, generalisation is impossible. Under these circumstances our best plan is to consider certain general points on which an answer to the question must necessarily be based.

It is evident that after-fellings can be commenced only—

(i) *When the seedlings have become thoroughly lignified.* Without such lignification they could neither recover if bent or crushed down in the felling and export operations, nor conduct water rapidly enough from the roots to the crown to meet the increased waste by transpiration due to the brighter illumination, nor resist the extreme atmospheric influences let in by the opening out the leaf-canopy.

(ii) *When they have developed a sufficiently long tap-root and numerous side roots* so as to be able not only to absorb a large quantity of moisture and nourishment from the soil, but also to be more or less independent of the upper layer of the soil which dries up in the hot weather and is liable to wide and rapid variations of temperature.

(iii) *In the case of broad-leaved trees, when the young seedlings have developed a sufficient number of strong collum-buds,* which alone can give them the faculty of shooting up again as often as they may be killed down to the ground.

(iv) *In the case of conifers, when the young plants have begun to develop a true shoot, i.e.,* not until they have ceased to consist of a thin stem crowned with nothing more than the tuft of cotyledonary leaves.

Besides the preceding four considerations, the following circumstances also regulate the time for the commencement of the after-fellings :—

(*a*) *The abundance of the new generation.* The more-plentiful the seedlings are, the better will they be able to afford protection to one another and also to the soil, and to prevent the establishment of a growth of masterful weeds.

And not only this, but in proportion to their abundance will be the number that can be spared for inevitable casualties. Hence if seedlings are few and far between, the first after-felling must be delayed.

(*b*) *The natural abundance or scarcity of invasive weeds and brushwood.* The more abundant such growth, the later must the first felling be made, provided of course other more important considerations do not order otherwise.

(*c*) *The age of the standing trees and of those removed in the seed felling with special reference to the maximun coppicing age of the component species.* With a number of stools present, still able to throw up coppice shoots, it would be highly unadvisable to make large openings in the leaf-canopy before the seedlings have acquired a certain amount of strength. As opposed to Europe, where hardly any trees coppice at all after the age of 60 years, many of our species coppice vigorously after they are a century and a half old, *e. g. Terminalia tomentosa*, sal, &c.

(*d*) *The richness of the soil.* The greater the fertility, the later, as a rule, ought the first felling to be made, for in proportion thereto will be both the rankness of the noxious undergrowth and the shade-enduring capacity of the seedlings.

(*e*) *The nature of the climate and locality.* The greater the extremes that prevail, the longer must the first after-felling be delayed.

(*f*) *On the shade-enduring capacity of the component species.* The more shade-avoiding the predominant or principal species, the sooner must a felling be made.

(*g*) *On the hardihood of the component species.* The hardier the species are, the earlier, provided there is no danger of a strong growth of weeds, brushwood and coppice shoots coming up and the soil does not require much protection, must the seedlings begin to be uncovered.

(*h*) *Rapidity of growth of the species in the seedling stage.* The more rapidly the seedlings grow, the more light will they require even simply to continue healthy, and the sooner, therefore, must they be admitted to an increased enjoyment of light. But this very rapidity of growth enables them to meet their crowns and close over the ground quickly, thus diminishing the importance of the nurse crop.

It will thus be seen that even in the case of one and the same species no hard and fast rule can be laid down to fix the exact time when the after-fellings shall begin. In each particular instance, the special circumstances prevailing can alone indicate when the first felling should be undertaken. In the absence of local experience, the following golden rule, which will at any rate preserve one from committing serious, if not fatal, errors, should be observed :—

If the seedlings are thriving, have a healthy colour, possess abundant foliage, strong shoots and large full buds, we may be sure that the existing amount of cover is doing them no harm; but if they are thin and lanky, have spare foliage, small weak buds, and almost abortive shoots, and present a yellowish appearance, or if they are found bending over to one side in the direction of an opening in the leaf-canopy, it is a clear sign that they require more light.

Usually the first after-felling will not be delayed beyond the third year succeeding the seed-felling.

III. Number and periodicity of the after-fellings.

In order that a single clear after-felling may be justified, the following six conditions must co-exist:—

(1) The climate must be extremely mild and otherwise favourable.

(2) The soil should be thoroughly suited for the seedlings and suffer no serious deterioration from complete exposure during several years.

(3) The growth of weeds, brushwood and coppice shoots should be practically *nil*.

(4) The seedlings themselves should be very hardy and tenacious and grow up rapidly.

(5) The seedlings should be abundant enough to close over the ground within a limited period, say 6 or 7 years.

(6) The area of the coupe should be limited to a maximum of a few acres.

The coincidence of so many circumstances, many of them of an exceptional character, can rarely be expected to occur, and it will thus be an almost invariable rule to effect the removal of the parent stock in more than a single operation.

Strictly speaking, indeed, an after-felling should be made as often as any considerable number of seedlings require more growing room in the soil or light above ground; and this would mean making such a felling nearly every year. Such frequent repetition is however generally impracticable; nor is it really necessary, for seedlings, particularly such as have become well lignified and have not entered the stage of rapid upward growth, hardly suffer for the first 2 or 3 years under cover that is only slightly in excess of their requirements in respect of light, especially if that cover is high. Moreover annual felling and export operations would give no time to injured seedlings to recover.

Hence there will nearly always be a short interval of years between two successive fellings. The length of this interval will be directly proportional to the shade-enduring capacity of the seedlings, and inversely proportional to their hardihood and rapidity of growth, the favourable nature of the soil, locality and climate, the absence of invasive weeds and brushwood, the openness of the seed felling, and the severity of the immediately preceding after-felling. And the number of the after-fellings will depend on the interval of time at which they should be repeated, on their severity, and on the amount of stock left standing in the seed coupe.

Usually the interval between one felling and the next will be from 3 to 5 years and the number of the fellings, including the first and the final ones, will not exceed 4 or 5.

IV. When to make the last after-felling.

The last felling should be made only when the great body of the seedlings have everywhere become established, have entered the stage of rapid upward growth, are out of all danger from the prevailing injurious weather influences, and can join crowns and close over and protect the soil within the next two or three years; and it should never be delayed until they have got beyond the early sapling stage, otherwise the damage caused by the felling and export operations will be so excessive as to entail considerable loss of production and costly repairs. We have said "the great body of the seedlings" advisedly, for the conditions of vegetation can never be so uniform as to justify us in expecting every point of the coupe to become completely stocked with seedlings all in one and the same stage of growth. The presence of small scattered blanks or incompletely stocked places or patches of younger or older growth ought never to be allowed to delay the final felling, when the rest of the new generation demands it. This felling will thus generally follow from 10 to 20 years after the seed felling.

V. What to remove in the after-fellings.

In a general manner it may be laid down that whatever trees interfere with the growth of the seedlings or are not required for their protection should be removed. But, in actual practice, this general rule is subject to certain qualifications imposed by the condition of the parent crop and the nature of the soil, climate and species. All the circumstances which demanded a

dark seed coupe will also prevail to enjoin moderation in the after-fellings. If the interests of the parent crop or the preservation of the soil or the necessity of keeping out drought and climatic extremes require it, the seedlings must, for the time being at least, be sacrificed to the extent of being temporarily kept back, without however actually suffering in their vitality.

Usually trees standing over strong or weak growth should be taken out before those overtopping seedlings of average size and vigour. Both strong and weak plants obviously require brighter illumination than these last, the first to be able to assimilate sufficiently actively for the sustenance of their larger parts, the second, possessing little or no tenacity, to be saved from immediate death.

Consistently with the safety of the seedlings and of the parent crop and the preservation of the soil, all trees that have ceased to increase in value must be taken out. Such will include all dead, unsound and badly mis-shapen trees, those in their decline, and those which have ceased to make any appreciable increment. Similarly, trees belonging to species, of which a sufficient number of seedlings have already come up and the appearance of more would be detrimental to the new generation, should be got rid of. So also, if there are any individuals young enough to send up, when felled, an abundant crop of coppice shoots, they should be removed as early in the series of after-fellings as possible, because the later they are felled, the more difficult will it become, under the continually diminishing leaf-canopy, to prevent an abundant regrowth from them. Trees with low or large spreading crowns should also, if circumstances permit, be taken out.

Wherever reproduction has failed or come up in an incomplete manner, and wherever in mixed forest, although seedlings may be numerous enough, certain species are insufficiently represented, there seed-bearers should be carefully preserved in order both to produce seed and protect the soil as well as to act as nurses later on. This rule cannot, however, obviously apply to the last after-felling, and its importance naturally diminishes with each successive after-felling.

The principle of the last after-felling is of course to remove every surviving tree of the original parent crop. If any trees were left, their felling and export would cause very serious damage among the close-grown saplings of the new generation. Nevertheless the production of very large timber for certain special pur-

poses is a necessity that must be provided for, and the more promising, sound and well-shaped trees must, therefore, perforce be spared until they attain the required dimensions. But when such is the case, every endeavour should be made to select the trees in question along roads and other export lines or in groups, with a view to minimise and localise the inevitable damage to the young crop.

VI. Marking the trees to be felled.

Here also it is the trees to be felled that should be marked. In the last after-felling it would of course give less trouble to mark the few, if any, trees reserved to acquire specially large dimensions. But as the fellings are made in the sole interests of the new crop, it is obviously very much more conducive to efficiency to mark those trees which, as the working party progresses, are found to be in the way of that growth and are not sufficiently promising or conveniently situated to be preserved.

In selecting trees for the preparatory and seed fellings the attention had to be directed mainly or solely to the condition of the leaf-canopy; for the after-fellings the attention has to be equally divided between the canopy above and the new growth on the ground beneath, and if there is ever any inequality, it is the latter that demands the more careful scrutiny.

The necessity of carrying out the work of selection and marking while the trees are in full leaf is more urgent here than even in the case of the preceding series of fellings, for at any other time many of the seedlings would escape notice, and at any rate there would be very great difficulty in recognising the species to which they belong, in appreciating their abundance and hence also their proportional distribution, and in judging of their health and vigour, and, in numerous instances, even whether they are alive or dead.

The selection of the trees should be effected in accordance with the principles enunciated in the preceding sub-article, and the work should go on from sweep to sweep as in the case of the preparatory and seed fellings. The system of re-examination recommended for the seed felling (see p. 372) may be adopted here, but it will seldom be justified, except perhaps in the first or first two after-fellings. The width of the sweeps will be determined by the distance on either side of him, up to which the selecting officer can conveniently and accurately note the condition of the young growth and the density of the cover overhead.

VII. Execution of the fellings.

The execution of the after-fellings is a complex operation consisting of several distinct works as follows :—

1. The actual felling and lopping of the parent trees;
2. The removal of epicorms.
3. The removal, cutting back or topping off of inferior growth interfering with the reproduction of the more desirable species.
4. The cutting back of badly injured seedlings of the better species.
5. Completion of the regeneration by artificial methods.

1. *Actual felling and lopping of the parent trees.*

This operation must obviously be executed at that season of the year, at which the young seedling crop will suffer least damage. For all species without exception that season always coincides with the season of vegetative repose. It is then that the seedlings are most elastic, least brittle and best able to recover from injuries, since lignification is then most complete, the seedlings themselves contain their maximum of reserve matter and possess the largest number of buds in a perfectly quiescent and, therefore, their least sensitive condition; and the very absence of vegetative activity, it is almost a truism to say, means that the loss of even a comparatively large number of organs can cause no shock to any process of growth. If the species are deciduous, the absence of leaves must very appreciably lighten the fall of the trees and restrict the area over which the seedlings can be damaged. But where continuous frosts prevail in winter, all work should be stopped while the frosts last, for the frozen seedlings will necessarily be extremely brittle. On the other hand, felling in the snow, provided there is no hard frost going on, is always to be recommended, especially on steep ground, for seedlings buried in the snow could not be under better shelter. Thus, according to the forest region, the best time for felling may be the latter part of autumn and early winter, or that part of autumn and the whole of winter, or the whole of winter and the first few weeks of spring, or the latter half of the cold weather and the whole of the hot weather, and so on.

As regards the actual felling and lopping, the same procedure should be followed as in the preparatory and seed fellings; but here, on account of the young reproduction, it will not always be possible to grub out the trees, although in a financial sense the operation may be remunerative, and the lopping of trees before felling must be much more general.

2. *Removal of epicorms.*

The preparatory fellings never admit enough light to provoke the appearance of epicorms, which cannot develop either in dark seed coupes. The removal of epicorms is necessary only when the exploitation of the affected trees is still so remote that they will have time to render knotty the utilisable concentric rings of the bole and to strengthen themselves at the expense of the crown, thereby possibly rendering the trees stag-headed. If the trees are to be felled within the next five years, the retention of the epicorms can generally do little harm.

The tools used for removing epicorms should be either light hatchets with a broad cutting-edge, or bills, or pruning hooks, or saws with a thin blade and fine, but strongly set, teeth. Of these various tools the first two, being more expeditious and easier to use and making a perfectly clean section, are to be preferred. Pruning hooks, of which Fig. 2 represents an excellent pattern, have their place only when the epicorms are very small and break off easily, and the advantage they offer is that with them the operator can reach a great height above himself. The cutting-edge forming the extremity of the tool represented in Fig. 2, may be used like a chisel from below upwards. The saw may also be attached to the end of a pole, as shown in Figs. 110 and 111. Bow saws buckle less and are easier and less fatiguing to work with than saws of other patterns. In using the hatchet or bill-book the blow should be delivered from below upwards, otherwise, however sharp the tool may be, the branch is almost certain to be wrenched or torn off, with a piece of the bark and even wood of the bole attached. Under any circumstances, the epicorms ought to be taken off flush with the bole and with as clean a section as possible, so as to prevent the formation of dead snags and to enable the wound to close over quickly before decomposition can make any progress. In order to reach the epicorms, the workmen should employ light ladders (those made of unsplit bamboo are the best), or simply a strong straight pole or bamboo with short bars of wood passed through at the requisite intervals, or triangular pieces of wood nailed alternately on two opposite sides. To prevent any chance of slipping, both ends of the pole or bamboo should be shod with a strong two-pronged fork (Fig. 112). Climbing irons should never be used, as

the points penetrate right into the sapwood and give rise to unsoundness there.

3. *Removal or reduction of inferior injurious growth.*

Wherever regeneration has completely failed but there is still time for the new growth to make its appearance and establish itself, there the soil should be cleared as in a seed felling. Sometimes an important species may be wanting or insufficiently represented in the midst of an otherwise complete reproduction; here also if there is time and any hope of the defect remedying itself, the ground should be cleared in patches as for a seed felling.

It will often happen that seedlings are kept back or threatened with suppression by weeds, brushwood and coppice shoots, and even by larger, older and denser and more rapid-growing seedlings of inferior or otherwise less desirable species. Weeds and brushwood should, if possible, be pulled up by the roots; and an overcrowded condition may also be remedied in the same way by taking out the harmful and least desirable individuals. Seedlings of species that cannot bear close contact of roots or crown with neighbouring individuals should have the soil *completely* cleared round them over a rudius of from 6 inches to 1 foot. Coppice shoots ought always to be cut back or, if they are stool-shoots, broken off at their insertion on the stool. If the stools can be killed, so much the better.

Where the growth is not too crowded, the obnoxious individuals of the seedling crop should not be killed, but only cut back or merely topped off. They should be cut back, if the seedlings to be saved or encouraged are very small or are comparatively slow growers, or if the growth requires a little thinning out. They should be topped off, if the seedlings to be released from suppression are already of some size or are old enough to begin to shoot up rapidly, and the growth is not dense enough to dispense with the help of the obnoxious seedlings in forming the leaf-canopy. The height at which plants should be topped off, will depend on the height and condition of the seedlings in whose interests the operation is required and on their own rapidity of growth. If those seedlings are about to start rapidly upwards, the overtopping plants should be just reduced to their level. If these latter grow up more quickly, then they should be cut down proportionately lower. In cutting back or topping off, the great principle

to bear in mind is never at any time to let the obnoxious seedlings get ahead of their neighbours, but always to keep them on a lower level so that, while constantly pushing up the latter, they may help to always maintain the leaf-canopy full enough to protect the soil and effectually prevent any growth of weeds and brushwood.

The work here described should be done only by a thoroughly trained and experienced establishment, never by contractors or by labourers employed from day to day.

4. *Cutting back of injured seedlings.*

Seedlings required to form the future forest, but so badly crushed or broken as to be unable to continue growing up vigorously and well-shaped and in a healthy and sound condition, should be cut back in order to reform themselves completely from the stool. They should be taken off as near the ground as possible and with a clean section. The tools to use are pruning knives (Fig. 114 represents a most effective pattern) or strong shears (Figs. 115 and 116). But if the stems exceed 1 inch in thickness, they must then be cut with a single blow from a light hatchet or bill-hook, as described on p. 404 under regeneration by coppice.

5. *Completion of the seedling crop by artificial methods.*

Recourse must be had to artificial regeneration in five several cases as follows—

(i) *To stock complete blanks.* In the case of small blanks, as there is always a likelihood of their being sown by the surrounding trees, it is advisable, before undertaking their artificial regeneration, to wait until the last or last-but-one after-felling, and then to use plants of more or less the same size and vigour as those forming the surrounding naturally-produced young crop. Otherwise the blanks should be sown up immediately after the seed felling, if sowing is justifiable, or planted up with the class of seedlings most likely to assimilate themselves with the future self-sown crop.

(ii) *To restock places where natural regeneration has completely failed in spite of the presence of seed-bearers.* Here we must plant seedlings of about the same size and vigour as the surrounding growth, for it is an essential condition that the new crop should not show too great a disparity in its several parts. This work should be taken up only at the last after-felling, unless it is considered hopeless to wait until then or unless the species used is delicate or shade-enduring.

(iii) *To fill up incompletely stocked places.* Here resort to artificial methods of regeneration must obviously be delayed until the last after-felling. The necessity of using a similar class of plants to those composing the natural growth is still more necessary here than in the preceding case, in order to prevent the newly introduced seedlings from being suppressed.

(iv) *To increase the proportion of a species that is insufficiently represented in the naturally produced crop.* Here it is best to plant on a rectangular pattern in order to economise labour, money and seedlings. If the species in question is shade-enduring and delicate, rather smaller plants than those composing the natural growth should be used; otherwise the same rule as before should be followed. Wherever a new plant has to be put down, natural seedlings, if any, should be dug up by the roots. The planting cannot be commenced earlier than the last but one after-felling.

(v) *To introduce a new species or one that has no fertile representatives in the parent crop.* Here we will sow, if the species and attending circumstances permit of it; and then the work will generally be taken in hand immediately after the completion of the seed felling. Otherwise it will be necessary, as soon as the leaf-canopy is open enough, to plant seedlings of the size most likely to be successful.

ARTICLE 4.

VALUE AND EMPLOYMENT OF THE METHOD.

In order that the procedure sketched out in the preceding articles may be feasible, it is evident that the entire crop operated upon each year should present throughout a general uniformity of aspect and conditions, without any tendency to unfavourable extremes. The forest is opened out over such large areas that, unless both the soil and climate were favourable and the species reproduced themselves very freely, failure, occurring as it would do, after a bright seed felling or the first or second after-felling, would be fatal to a second crop of seedlings coming up or establishing itself. If natural regeneration by seed is still persevered in, the very causes that led to the first failure would be again effective, but this time more so than before, since the soil will have deteriorated from exposure and the more open leaf-canopy will be able to afford still less protection to any seedlings that may be produced. Ultimately, recourse to artificial methods of regenera-

tion, which would perhaps have been easy if adopted at the very commencement, but have now become proportionately difficult, tedious and expensive, cannot be avoided. If the locality is exposed to storms, and the trees composing the crop are shallow-rooted, then the moment the seed felling or the first after-felling is made, some get blown down, bringing down others in their fall and giving free entrance to the wind by the gaps they leave. All this proves that, even if natural conditions are favourable, great caution must be observed in making the seed and after fellings, and success requires patience and waiting.

If the crop is pure, the soil and climate should present no marked diversities and should be more or less favourable to the vegetation and reproduction of the component species; while the trees themselves should be more or less of one and the same age, height and vigour, so that effective seeding may be simultaneous and the new plants may make their appearance and start up all together. Moreover, the species itself should be able to protect the soil and preserve it in an efficient condition for germination and for the early establishment of seedlings.

If the crop is mixed, the requisite conditions become much more complex. A mixed crop may be composed either (A) mainly of a single strong gregarious species, or (B) mainly of two such species, or (C) mainly of more than two such species, or (D) of numerous species, none of which shows any tendency to become gregarious.

A. *If the mixed crop is composed mainly of a single strong gregarious species,* we have a case resembling that of a pure forest, with the exception that the presence, however restricted, of the companion species renders the regeneration more certain. But it is necessary that the gregarious species should be one possessing a high market value and for which there is an extensive demand; otherwise the uniform age and height of the crop will only favour the exclusive species at the expense of the more valuable ones, already in far too small a minority, and the present method of regeneration becomes inapplicable.

(B.) *We will here suppose that the mixed crop consists mainly of two strong gregarious species.* Then if neither of the two is much sought after, whereas some of the rest have a high market value, the adoption of the uniform method is entirely out of the question, for nothing could be worse in the interests of these latter. But if the gregarious species are also valuable and sell

readily, the method may be adopted and we may have any one of the four following cases—

(i) They may be equally tenacious and attain more or less the same stature. Here if they are also equally light demanding, they must either seed and reproduce themselves simultaneously, or, in the event of one of them being much the more valuable, the latter may be allowed to seed first. But if one is more light-demanding, that one ought to be able to appear first in the new crop.

(ii) They may be both more or less equally tenacious, but one of them is capable of reaching a higher stature. In that case, either the taller species should be open-crowned and seed earlier, especially if it grows more slowly, or the requirements of the two should be so different that they cannot interfere with, but help, one another, when they may be allowed to reproduce themselves simultaneously.

(iii) One may be more tenacious than the other, although their statures are equal. Then, if the weaker is the more valuable, but is not very much more prolific than its rival, it should be able to reproduce itself sufficiently in advance not to be caught up and suppressed by the latter; otherwise the two should appear simultaneously in the crop.

(iv) They may be unequal both in tenacity and stature. Here it is essential that the less tenacious should be the taller of the two; and its reproduction should be contemporaneous with, or precede, that of the other, according as it does or does not grow up more rapidily in the seedling stage, or does or does not reproduce itself more abundantly.

C. If there are more than two strong gregarious species, we have merely a more complex case of hypothesis B, but the uniform method is rarely applicable.

D. When the crop is composed of numerous species none of which has any tendency to become gregarious, we have the most complex case of all. But usually the uniform method is inapplicable here, owing to the complete uncertainty of securing, in the desired manner and proportion, the reproduction of so many species possessing such opposite habits and requirements. But when its adoption is practicable, it is to be recommended only in the solitary instance of the most valuable species of the mixture being also the most tenacious, and being also sufficiently evenly distributed to profit by the uniformity of growth and thereby increase its numbers on the ground. Its superior tenacity may be

due to some or all of the following characters:—greater shade-enduring capacity, more rapid growth, higher stature, greater suitability of soil and climate.

We thus see that the uniform method will have its widest application in pure forests and in mixed forests composed principally of a single valuable gregarious species, only a restricted one in forests consisting of more than one gregarious species, and little or none at all in other classes of mixed forests. Provided the gradients are not too steep, or the soil or aspect unfavourable, or the elevation too high, it is generally extremely well adapted for *Pinus longifolia* pure or mixed with *Quercus incana*, for *Quercus incana* and *semecarpifolia* pure, for deodar pure or mixed (especially with oak), for forests of sal, *Pterocarpurs Marsupium*, *Mesua ferrea*, &c. It will sometimes suit even teak.

One great and, at present, insurmountable obstacle to the general adoption of the method in this country, in the numerous large tracts for which it is otherwise suitable, is the fact that in respect of timber the demand is usually limited to one or two of the component species, and in respect of both timber and firewood the demand is equal to only a small fraction of the production. No, doubt trees that cannot be sold, but must be got rid of for cultural reasons, may be killed by girdling and allowed to rot standing; but this is a method of getting over the difficulty that is practicable only where the *majority* of the trees composing the forest are saleable.

Where, however, the uniform method is applicable, its employment brings with it many very important advantages. As the work of regeneration does not spread over the whole forest and go on at all times, but in each year is confined to a definite area which is only a very small fraction of the entire area of the forest, labour can be better organised, directed and supervised, thereby securing greater efficiency and economy, the damage to the forest growth, inevitable in all felling and export operations, is localised and minimised, and is, therefore, more easily repaired, and labour-saving contrivances, such as sawing machines, sledge-roads, slides, tramways, floating, &c. can be adopted for the conversion and export of the large accumulation of produce in one place. As the coupes may be made to follow each other on the ground in the order of their dates, the same export line as has served the previous year has only to be slightly extended into the new coupe. Then the successive coupes form a regular gradation of ages, so that if parts of the forest must be kept open for grazing

or for any other purpose, only those areas need be thrown open in which the crops are old and tall and strong enough to run no risk of injury. Lastly, the lines on which work is to proceed can be previously laid down with such systematic regularity, that the least possible margin is left to individual discretion, so that foresters of only average intelligence and training are competent to carry it out, and the chances of fatal mistakes are minimised.

SECTION V.

The group method.

Whatever forest we may examine, we shall nearly always find that it consists of a number of homogeneous parts or groups. If such groups are conveniently distributed and large enough to furnish each an annual coupe, they may be regenerated by the uniform method just described. But whatever their size and distribution, although that method may not be applicable, nevertheless there will be nothing to prevent each individual group by itself from being regenerated by means of the regular series of fellings constituting that method. Thus we get the *group method.* The group method then differs from the uniform method, not in its detailed procedure, but merely in the application of that procedure. In the latter method, a large compact area is operated upon in any one year and the work of regeneration progresses successively from one such area to another similar one, irrespective of any differences of treatment which individual parts of each area may require ; whereas, in the former method, each group, enjoying a uniformity of conditions, is treated on its own individual merits, independently of the condition and progress in regenerae tion made in the surrounding groups, except in so far as thesare able to afford shelter, pass in light laterally and contribute towards the sowing of the ground. For instance, to take an extreme but frequently occurring case, one group may be full of advance growth requiring being immediately uncovered, while the next one may contain no seedlings at all, and not even a fully fertile tree; under these circumstances we would at once make the last after-felling or a heavy intermediate one in the first group, but only a preparatory felling in the second.

The differentiation of a forest into dissimilar groups will of course be due to one or more of the following causes :—varying aspect, elevation and gradient, the varying influence of dangerous winds, the varying depth, physical characters,and chemical composi-

tion of the soil, the varying quantity of moisture in the soil, the varying subsoil, &c. An important consequence, flowing from the great principle of independent treatment on which the group method is based, is that no group is taken in hand for regeneration unless circumstances are ripe for it, unless, in other words, its success is from the very beginning assured.

We will now pass on to consider to what extent and in what manner the three classes of regeneration fellings described under the uniform method can be applied in the present case.

ARTICLE 1.

THE PREPARATORY FELLINGS.

It will often happen that when a group is taken in hand for regeneration, it already contains advance growth; the presence of this advance growth proves that preparatory fellings would be superfluous and ought to be altogether omitted. In other groups it will be found that the trees require encouragement in order to become good seed-bearers and nurses, and that the soil is not in a fit condition for the reception and germination of seed and the prosperous growth of the resulting seedlings; in such groups the preparatory fellings cannot be dispensed with, but they will assume a different character according to the special conditions obtaining. In one instance, the trees in the group may be thin and weak-crowned and be unable to sow the ground for many years to come but if surrounding groups contain good seed-bearers capable of sowing the greater portion, if not the whole, of the area of the group in question, the preparatory operations as such will be limited mainly to improving the soil, and in any felling that may be made, the preparation of the trees as seed-bearers and nurses will be subordinated to the constant maintenance of a protection-affording leaf-canopy and to the thinning out of the forest growth for increased production. This thinning will be confined to the removal of weak, suppressed or unhealthy and unsound trees and of those that are low-crowned, and the leaf-canopy will never be opened out to the same extent as under similar conditions in the uniform method. In another instance, with a similar stock in the group to be operated upon, the surrounding groups also may contain unfertile trees; in that case, the preparatory fellings will be made on the very same principles as in the uniform method. So also, if the group covers so large an area that the surrounding groups can exercise any influence on its vegetation and reproduc-

tion on only a very small fraction of its extent. And so on. In any case, the degree to which the leaf-canopy ought to be opened out will, unless the area is very large, always depend on the density of the surrounding groups, the share they can take in producing the new crop, and the extent to which they themselves may bear being thinned out in order to let in light sideways, That is to say, under no circumstance will the leaf-canopy be opened out in any marked degree or over any considerable area. a result all the easier of realisation by reason of the invariable rule followed of undertaking regeneration operations only where conditions are favourable to success.

We thus see that preparatory operations lose here much of the great importance which necessarily attaches to them in the uniform method. Often they are entirely redundant, aud where they are required, they not unfrequently assume more the character of an ordinary improvement thinning (See BOOK III, Maintenance and Treatment of Forests).

ARTICLE 2.

THE SEED FELLING.

Like the preparatory fellings, the seed felling often becomes unnecessary on account of the presence of advance growth. Where there is no advance growth, there of course it cannot be omitted; but in proportion to the diminishing size of the group, and the increasing certainty of complete sowing from outside, it gradually dwindles down to a mere preparation of the soil, the effects of which need not last beyond the following two or three years. Consistently with the principle, always to be observed in the group method, of keeping the leaf-canopy every where as full as possible, the seed coupe, except when the area of the group is extensive, will generally be darker than what would in similar circumstances be required under the uniform method; for in addition to the various considerations which regulate the severity of the felling in that method, we have the two following:—

(i) *Lateral illumination.* If the surrounding groups are open enough, a considerable amount of sidelight must already enter under the leaf-canopy; and, if the growth in those groups is very dense, it will always bear being thinned out, thereby saving to a certain the leaf-canopy in the enclosed group.

(ii) *Protection of adjoining groups.* If these have, owing it there to work or accidents, become open, their safety demands

very light fellings in bordering forest, particularly that to windward. But, as frequently said before, a close leaf-canopy overhead is compensated for by sufficiently bright lateral illumination.

Another point to specially note in connection with the group method is that the seed felling may be undertaken even in the total absence of fertile trees within the area of the coupe, provided such trees stand outside to windward of it. Hence, under favourable circumstances, regeneration may be commenced at an earlier age than in the uniform method.

ARTICLE 3.

THE AFTER-FELLINGS.

These are the only fellings of the regeneration series that can never be dispensed with. Even more than in the seed felling, the character of the surrounding groups has to be studied and must be allowed to exercise its full influence on the progress and establishment of the seedlings and the maintenance everywhere of an unbroken leaf-canopy. Thus, in a small group surrounded on every side by full-cropped groups not yet under regeneration, the after-fellings will be severer than they would, under similar circumstances, be in the uniform method, and the last after-felling will be made earlier, for the surrounding forest will afford the additional amount of protection required. These severer and earlier fellings must react on the bordering forest by letting in light sideways and serve them as preparatory and seed fellings combined, so that beginning with a small completely regenerated group as a centre, the regenerated area will go on ever widening. On the other hand, in a large group, enclosed between others the regeneration of which has been completed, the after-fellings must be lighter, more frequently repeated and spread over a longer period, especially along its edge, which indeed from the very outset will enjoy lateral illumination from outside. The procedure will be slowest and most cautious if the surrounding groups contain an open crop with little or no reproduction on the ground.

What we have just said may be resumed thus :—Allowing fully for the relative influence on one another of neighbouring groups, the after-fellings should be made on the same principles as those laid down for similar fellings under the uniform method; and according to the character of that influence, those fellings will be rapid and heavy or protracted and light.

ARTICLE 4.

VALUE AND EMPLOYMENT OF THE METHOD.

This is, *par excellence*, Nature's own method. Its principal characteristics are as follows :—

(i) The regeneration fellings are undertaken only over advance growth or where Nature gives unmistakable indications of success by herself preparing the way.

(2) Every group is made, to the utmost of its capability, to directly assist the vegetation and regeneration of the adjoining groups.

(3) Regeneration begins comparatively early, certainly earlier than in the uniform method.

(4) The leaf-canopy is constantly maintained as full as possible, consistently with the unimpeded growth of the trees and the seedlings, so that the fertility of the soil is maintained at its maximum and injurious weather influeuces are effectually kept out.

(5) The entry of each group upon its regeneration and its passage from one stage of regeneration to the next is a gradual process, admitting of no violent changes, such as necessarily occur in the uniform method, in which every portion of a coupe is rigidly subjected to one and the same operation.

(6) The treatment of each group according to its own special requirements, and the absence of uniformity of age or height, except over very limited areas, are specially favourable to a mixed growth and to the just apportionment to each species of the place due to it.

(7) As the groups undergoing one and the same class of regeneration fellings are necessarily detached from one another and constitute severally only a small fraction of the aggregate area, failures due to unavoidable accidents or bad work are localised, and do less harm and are more easily repaired than if all the groups formed one continuous area.

(8) The method admits of so much elasticity of execution that a fluctuating demand can be at once met; and the forest can be regularly worked, even when the demand is very much below what it can yield or is confined to certain species and classes of produce out of the many it can furnish.

(9) The regeneration of any individual group, when once it has been taken in hand, is generally a rapid process; but the aggregate time required to regenerate a continuous mass of forest, the com-

ponent groups of which necessarily enter upon their regeneration at different times, usually extends over from 30 to 40 years, and, if we include the age of the advance growth utilised, to even 50 years.

(10) This is the most expensive of the methods of natural regeneration by seed, and its application requires the highest degree of skill, care, watchfulness, activity and industry, and therefore demands a much more specialised and stronger establishment than the uniform method.

(11) The scattered fellings necessitate a long and intricate system of roads.

Characteristics 1-8 are unmixed advantages of the highest order. Characteristic 9 is in no sense a disadvantage, for while the new generation is gradually making its appearance, the annual increase per acre, thanks to the constantly full leaf-canopy, and the early commencement of regeneration (Characteristics 4 and 3), can still go on undiminished. Nor is characteristic 11 absolutely a disadvantage, for under no other method of regeneration applicable to a forest, in which conditions varied from place to place, could export be rendered easier. Characteristic 10 is certainly a disadvantage in the present backward condition of India.

The group method is specially suited for forests in which the soil, locality and species and condition of the crop exhibit wide divergences at short intervals. A forest may contain numerous places, where, owing to the deterioration of the soil, or to damage to the stock by snow or fire or animals or from previous unrestricted enjoyment, or to the presence of groups of very much younger trees than the predominant age-class, &c., it may be necessary to begin regeneration at once before the operations can be extended into the immediately adjoining areas, thus laying the foundation for the group method. It is especially in mixed forests and in those, whether mixed or pure, in which advance growth begins to come up long before the trees are large enough to be felled, that the method will find its most obvious application.

SECTION VI.

The strip method.

DESCRIPTION OF THE METHOD. In this method also we make preparatory, seed and after-fellings, but the coupes do not extend over large irregularly shaped areas or coincide with well-defined homogeneous groups, as in the two preceding methods respectively, but form a

succession of long parallel strips of equal width running right through the forest or division of the forest, as the case may be. To take the simplest case, we will suppose that strip I (Fig. 116), having gone through the preparatory and seed stages, is now to be subjected to after-fellings; then strip II will be the seed coupe, strip III the preparatory coupe, and the area beyond still untouched forest, the regeneration of which is in due course to follow. Thus in each coupe in its turn the successive regeneration fellings follow one another in the same order as in the uniform method and are based on the same principles, except that due weight must be given, as in the group method, to the possibility of lateral shelter and illumination and to seed coming in from bordering trees. As in the group method, the preparatory fellings may become entirely superfluous; and, although the seed felling can never be dispensed with, yet wherever in the seed coupe a group of advance growth is met with, an after-felling must at once be made over it. The degree of assimilation in this repect with the group method will be in proportion to the irregularity of the forest.

If an interval of several years elapses between one effective seeding and the next, no seed felling will be made in the intermediate years, but each year a new strip will be brought under preparation, so that when the next seeding occurs, the seed felling will be made at once over as many strips as have been under preparatory fellings during that interval. When this happens, after-fellings will not, like the preparatory ones, progress by single strips each year, but will be made over the entire number of strips sown simultaneously. As seed fellings always yield a large quantity of produce, the deficit caused by their stoppage during any year must be chiefly made up by repeating the after-fellings more frequently than they would otherwise be made.

The width of the strips will of course depend on the soil, climate, configuration of the ground, component species, frequency and abundance of seeding, difficulty of germination, &c. In a general manner, the width will be in direct proportion to the ease and certainty with which regeneration can be accomplished. It may vary from 100 to several hundred feet, but when the forest is wanting in uniformity and the fellings assume somewhat of the irregular character that characterises them in the group method, it ought generally not to exceed the height of the crop through which the strip runs.

If any dangerous wind blows, the strips will run at right angles to it and, beginning from the further end of the forest, will succeed one another in the direction opposed to it. Otherwise they will be so aligned, as to take in the several parts of the forest as much as possible in the order of the urgency with which their regeneration is called for. If a hill is situated inside the forest, this order will generally be secured by following more or less closely contour lines (Fig. 117). The work of distribution will often be facilitated by adopting two or more series of successive strips as shown in Fig. 118, a procedure that indeed becomes obligatory when the forest is so narrow or so large that a single strip could not include the aggregate area of one year's fellings. These separate series of strips, besides satisfying cultural exigencies, should be so located as to serve separate markets and possess separate export lines, thereby securing easier distribution of the produce and higher selling rates.

VALUE AND EMPLOYMENT OF THE METHOD. This method enjoys all the advantages of the uniform method, while, owing to its always keeping the ground well covered, it prevents the risks which, in that method, necessarily accompany failure in regeneration. In this respect, and in that it can be adapted to the regeneration of fairly irregular forests by narrowing the strips and utilising every patch of advance growth, it resembles the group method, to which it is superior in that the work is concentrated over a will-defined narrow strip of ground, which, if level enough, would form the most advantageous export line. The process of regeneration is longer than in the uniform method, and may be quite as long as in the group method. Lastly, its employment requires much less skill, care and labour than that of the group method, and, if not more skill, at least somewhat more care and labour than that of the uniform method.

The strip method may be successfully applied in all areas, which present very marked divergences of soil, climate and stock, but it is especially in forests where a certain uniformity of growth has no undesirable consequences, that it will yield the happiest results. It may be employed on a large scale in the plains in forests of sal, *Pterocarpus Marsupium*, *Hardwickia binata*, *Terminalia tomentosa*, &c. Its adoption, however, presupposes a demand for all or most of the produce the forest can yield, as it is not so elastic as the group method.

SECTION VII.

Jardinage.

DESCRIPTION OF THE METHOD. In this method from one to several trees are taken out from various points, wherever advance growth or the condition of the crop requires their removal, and this operation extends at once over the whole area of the forest or, if the forest is very large, over a very considerable portion of it. Thus, as said before (p. 349), there is never any point of time when the original crop can be said to have ceased to exist and to be completely replaced by a new generation, and the process of regeneration is not, as in the other methods, limited to a definite period, but is expected to go on constantly, with no intermittence but what is due to intermittence of seeding.

As a rule, only the formation of the smallest possible gap consistent with the appearance and growth of new plants is permitted. Usually enough advance growth is to be found on the ground and there is no necessity for felling any trees with the special object of provoking the appearance of seedlings. The trees to fell are (*a*) those that are dead, dying or unsound or are unlikely to remain sound until the next exploitation, (*b*) any others which interfere with advance growth, and (*c*), if the quantity thus obtained is still short of the annual yield, also the less valuable or less promising individuals from overcrowded places. If the trees falling under class (*a*) are very numerous, none or very few of class (*b*) will require to be felled, and of course none at all of class (*c*).

The size of the gaps to be made will depend mainly on the extent and condition of the patches of advance growth, on the nature of the species, on the mildness or severity of the climate, on the character of the soil, and, in hilly country, also on the steepness of the gradients and the risk of landslips and erosion. The more unfavourable prevailing conditions are for the maintenance and growth of the forest and the appearance and establishment of new reproduction, the smaller must the gaps be, and in extreme cases no more than a single tree ought to be taken out from any point.

The formation of every gap over a patch of advance growth has always the effect, thanks to lateral illumination, of extending the patch in question in every direction; and, indeed, we may in a general manner say that, owing to the small size of the gaps made,

the importance of lateral illumination is greater here than even in the group method.

Places most apt for regeneration by jardinage are (1) where old trees stand singly or in groups, or (2) in the midst of an open crop of large poles, or (3) where there are small openings in the forest.

If the forest is small, the entire area has to be worked over every year; but whenever the area is large enough, it is much better to divide it into 5, 10 or more divisions and work them successively in rotation. Each division thus enjoys rest for several years, during which the seedlings continue to push on without being broken or crushed in the felling and export operations as fast as they recover from similar previous accidents. The duration of this rest, *i.e.*, the number of annual divisions, will depend on the average interval between two successive good seed-years, the quantity of old exploitable or deteriorating material on the ground, the density of the stock, and the shade-enduring capacity and rapidity of growth of the young reproduction.

VALUE AND EMPLOYMENT OF THE METHOD. Six very important advantages accompany the employment of the method:—

(i) *Constant maintenance of the leaf-canopy in as full a condition as the species, soil, locality and climate will allow.* Hence jardinage is the best, and, in most cases, the only method to employ in forests or belts of forest kept up for the protection of slopes, for shelter against storms, cold and hot winds, &c., and in forests exposed to climatic extremes, as at high altitudes, on crests of ridges, in the midst or on the borders of deserts, &c., where an open growth would be fatal to the very existence of the forest growth.

(ii) *Constant maintenance and improvement of the fertility of the soil.* This is a consequence of (i). Whence the necessity of jardinage in forests growing on very rocky, stony, shallow or dry soils.

(iii) *Continued greater or less freedom of the soil from invasive weeds and brushwood.* This is also a consequence of (i).

(iv) *Certainty of regeneration,* thanks to (i), (ii) and (iii). By no other method is completely successful natural regeneration by seed certain, so that, wherever regeneration is a very slow and difficult process, there we must adopt jardinage.

(v) *Great elasticity in the working of a forest.* The exploitation can be made to respond at once, within the capability of the forest, to the most widely fluctuating demand both as regards

quantity and class of produce, and it is possible to organise regular work even if the demand is very small and embraces only a single class of produce. This is an enormous advantage in India, where there is hardly a forest that can be at all worked up to its full capability and the demand is limited to a few out of hundreds of species of trees and large shrubs.

(vi) *The little skill and experience required in applying the method.* This also is no inconsiderable advantage in India, where the habits and requirements of the various species are still so little known, and where for a long time yet we must be resigned to work with inadequate and inefficient establishments.

Opposed to these unquestionably great advantages, there are several signal disadvantages inseparable from the method. They are—

(i) *Heavy damage to standing forest* from the annually or all but annually repeated felling and export operations everywhere. Trees get bent, barked, mutilated or broken, and seedlings are killed or badly crushed. The result is a very large proportion of unsound and mis-shapen trees, and unhealthy and, therefore deficient production.

(ii) *Extreme irregularity of the growth and condition of the forest.* This produces a great deal of knotty. mis-shapen timber, composed of concentric rings of variable thickness and, therefore, liable to split, twist and warp.

(iii) *Necessary absence of improvement thinnings* (see Book III), the only equivalent operation, which is always very restricted and often altogether omitted, being the removal of trees additional to those that are dead, dying, unsound or likely to soon become unsound, or which are injuring advance growth (see p. 395, para 2). Sound and promising trees of valuable species get overtopped or crowded up against by inferior individuals, the result being further loss of production and faulty distribution of species according to their value. And even the survivors of the more valuable species, having exausted themselves in the struggle to get the better of their neighbours, may become permanently weakened.

(iv) *Unregulated regeneration,* a further cause of faulty distribution of species. Species that seed and germinate most freely and survive best under the circumstances peculiar to a forest worked by jardinage, are of course bound to predominate.

(v) *Deferred fertility,* due to the inevitable overcrowding. In consequence of this, trees have sometimes to be kept beyond

the age at which they would otherwise be exploited, another source of loss of production.

(vi) *Risk of the few species in special demand being exterminated,* and one of the principal advantages of the method, viz. elasticity of working, being converted into a serious danger. But a partial protection against this risk is afforded by the restriction of the fellings, in the case of those species, to trees above a certain high minimum girth.

(vii) *Protection and supervision rendered difficult and inefficient,* owing to the generally immense areas over which the regeneration, felling and export operations are spread. Hence the advisability of dividing up a large area into several portions and working each in its turn (see page 395, para 1).

(viii) *Impossibility of admitting grazing.* As regeneration is going on everywhere and at all times, the admission of cattle is never possible except at the sacrifice of the reproduction. This is a capital disadvantage in all right-burdened forests, which the soil, climate and other conditions prevent from being worked by any other method than jardinage. Either the rights must be curtailed or abolished, or the forests must eventually disappear.

From what precedes it is evident that jardinage is a method to be adopted only under the impossibility of applying any other, either because the forest or wood is too small to furnish a succession of coupes, or because forests or belts of forest kept up for purposes of protection must be maintained as full as possible, or because the soil and climate are extremely unfavourable for regeneration, or because the safety of the forest in storm-beaten localities or where snow lies heavy requires that the leaf-canopy shall never be opened out or the trees cease to give each other support, or because only a small fraction of the annual sum of production is saleable.

CHAPTER VIII.

REGENERATION BY COPPICE.

Regeneration by coppice may be effected by means of stool shoots or root suckers or culms or pollards, or of any of their combinations. The employment of the first obviously constitutes the most common mode of coppice regeneration, since all broad-leaved species shoot up again from the stool, whereas only a limited number of these can send up root suckers, and only the bamboos produce culms, while pollarding is the least used method of all, much less even than combinations of the first three.

SECTION I.

Regeneration by stool-shoots.

Success in regeneration from the stool depends on ten main factors as follows:—(1) the species, (2) the soil, (3) the climate, (4) the age of the stems cut back (5) the healthiness and soundness of the stools, (6) the longevity of the stools, (7) the manner of cutting the stools, (8) the season for cutting, (9) the location of the coupes, and (10) the presence of stores.

1. *Influence of the species.*

The conditions that regulate the relative facility with which the different species grow up again from the stool have already been fully studied on pp. 74 (last para.)—77, to which the student is referred.

2. *Influence of the soil.*

The soil affects reproduction from the stool by its fertility and suitability for the species in question and the repeated sudden temporary arrests of vegetation it may bring about (see p. 73-74).

3. *Influence of the climate.*

This influence is fully described on pp. 73-74 under the head of "Repeated temporary arrests of vigour of crown." The more

vigorous the growth is during the intervals between these temporary arrests of vegetative activity, that is to say, the more forcing the climate is, the stronger will be the production of the stool-shoots.

4. *Influence of the age of the stems cut back.*

This influence has been studied in detail on pp. 73 and 91. The older the stems are up to the limit when they contain their maximum number of dormant buds, the stronger will be the buds and the larger the shoots they produce. Mere number of stems will never make up for deficient age in this sense, for we want not simply an abundance of shoots, but also strong shoots that will push up rapidly as soon as they are produced. Obviously the limit of age here referred to will depend on the species, soil and climate. If the crop is actually often cut back before this limit is reached, it is simply because postponement of the exploitation until that period would result in diminished average annual production.

5. *Influence of the healthiness and soundness of the stools.*

Unsoundness or an unhealthy condition of the stool generally spreads into the daughter shoots, more in some species than in others, hardly at all, however, in teak, sal, *Terminalia tomentosa* and *Arjuna*, and many of our more valuable trees. In any case the foot of a stool-grown tree must always contain a part of the dead, decomposing portion of the parent stool, and the larger and the more badly cut this latter has been, the larger and more decomposed will be the portion of dead and rotting wood therein enclosed, and the greater the chance of unsoundness spreading into the foot of the tree and affecting the number and vitality of the dormant buds it contains.

6. *Longevity of the parent stool.*

No trustworthy data are available to show what relation exists between the natural term of life of a tree never cut back and the period of time up to which it can go on shooting up again as often as it is cut back. In the case of certain European trees, as the ash, maple, birch, &c., the latter term is certainly shorter, seldom lasting beyond the second or third coppice exploitation, whereas in the case of some others, notably many Indian species, such as teak, sal, *Terminalia tomentosa*, &c., no limit has yet been

observed to their continued reproduction from the stool. That soil and locality influence to a very great extent the duration of the coppicing faculty, there can be no manner of doubt; but in what way the peculiar attributes of the different species act in this matter, although in a measure suggested on pp. 71-77, still remains a question to be cleared up by future study.

7. *Manner of cutting the stool.*

HEIGHT OF CUTTING. The stools should be cut as near the ground as possible. The following are the advantages of cutting back flush with the ground:—

(i) The bark below that level, being protected by the surrounding soil, is thinner and softer than in the exposed parts of the stem and thus allows the dormant buds to come through more easily.

(ii) The most numerous and vigorous dormant buds lie in the portion of the stem inside the soil, where, protected from drought and atmospheric extremes, they have been multiplying rapidly since the formation of the original collum buds in the first year of seedling life.

(iii) The shoots, coming up out of, or immediately in contact with, the soil, develop roots of their own and become independent individuals at the latest in their second year, and thus continue growing up rapidly even after the reserve matter of the parent stool has been exhausted. On the other hand, shoots that come up at some height above the ground, never become independent stems, but remain all their life mere branches of the original stump.

(iv) The shoots, resting up against the soil, are less easily broken off. When the shoots first come out, they are connected with the parent stool only by a sort of articulation, and hence break off very easily. Shoots that spring up at some height above the ground, besides having no support, are more exposed to the wind. Moreover, while such shoots remain fragile for many years, until they have formed several concentric layers of wood common to themselves and the parent stump, the others soon anchor themselves firmly in the soil by means of the numerous new roots they send out in every direction.

(v) Stools cut flush with the ground, soon get concealed under the soil which retards their inevitable decomposition, and the rapid growth of their numerous daughter shoots soon covers up the most sensitive portion of the section (the region of the

cambium and sapwood) and excludes further atmospheric action. Where stools are cut high, the shoots, as a rule, spring from some point much below the section, which therefore always remains exposed to the weather.

(vi) Owing to the greatest thickness of a tree being at its base, the shoots that spring up thence form a wide circle of stems, several of which can therefore live, and thus furnish a very considerably increased number of stools at the next coppice exploitation. The result of this mode of increase is an ever-widening circle of clumps, which may all be traced to the original stool at the centre. The circular arrangement, necessarily, becomes eventually obscured, when several circles, widening out round their respective adjacent original stools, begin to intersect one another. The number of stools can thus increase in geometrical progression at each successive exploitation, and an originally open forest may thereby become denser and even fill up completely. It is obvious that if stools are cut above a certain height, no increase in their number is possible, for at each exploitation the very same tree has to be cut over again.

(vii) As a consequence of all the preceding advantages, each stool cut flush with the ground produces a thick spreading clump and contributes very powerfully to the early formation and closing up of the leaf-canopy and the protection of the soil, which is laid bare at every exploitation.

(viii) As a further consequence of the preceding conditions, when the stools are cut back flush with the ground, the trees remain sound and healthy right down to the base, and thus not only yield a larger quantity and higher quality of timber, but furnish better stools for the production of the next generation. Moreover the coppicing power of the trees is thereby prolonged.

Some species can throw up shoots from the lowest point of the crown of the roots, and this, even if the central portion of the stool has been removed and the main roots completely disconnected from each other, *e. g. Zizyphus spp., Prosopis spicigera, Acacia Catechu,* Teak, &c. If wood is valuable and the price of the additional wood secured at least covers the cost of the special operation, stems of such species, from about 6 inches and upwards in diameter, should be cut inside the ground or stubbed out altogether, according to the circumstances of the case. It is unnecessary to stub out smaller stools, as their insignificant size can not interfere with the soundness and health of the future coppice, and moreover

the small amount of wood in their underground portion would hardly ever be worth the trouble or the expense of getting out. Shoots coming up from some distance below the surface are evidently far superior to those springing up on stools cut flush with the ground.

There is only a single exception to the general rule laid down regarding the height at which stools should be cut, and that occurs when the area to be exploited is subject to be flooded or to become marshy. Excess of moisture in contact with the buds in the stools would produce decomposition in them and prevent the necessary amount of heat and air reaching them, and the force of the flood waters would break off the coppice shoots. Hence where floods occur, the stools must necessarily be cut just above the highest level of the water, and in land that becomes at all marshy, stubbing out cannot be thought of.

SURFACE OF SECTION OF THE STOOL. In cutting the stool above ground two main points should be constantly kept in mind :—

(1) The edge of the stool should *everywhere* be as near the ground as possible, so that every shoot may come up in contact with the soil; and

(2) Water should be able to run off directly it falls and no where collect on the stool.

Hence on a slope the section of the stool should be parallel with the surface of the ground; while on level ground the stool should be slightly higher in the middle and slope away thence in very direction to the circumference. In either case, the surface of section should be even and smooth, without any hollow that may catch water.

When the stool is cut inside the ground, the surface of section need not be very even, so long as no water can collect *over* it. When the stool is completely stubbed out, cutting through the top of the main roots in the least troublesome and fatiguing manner, *i.e.*, obliquely, also gives the very best section for the purposes of the coppice.

TOOLS TO USE. Only cutting tools should be used, *viz.*, axes and hatchets with broad blades, bill-hooks, pruning knives and shears. Saws are entirely out of place, as they leave a ragged, woolly surface, which absorbs water like a sponge and hastens decomposition. The weight of the tool should be adapted to the size of the stem to be cut; a tool that is too heavy penetrates

little, but gives violent shocks, which rupture the delicate root fibres and hairs and may altogether prevent any promising regrowth from coming up. The advantage of a bill-hook (Fig. 119) is that it is light and requires much less room than the axe to wield; but a hatchet is almost as good and its use is more easily learnt. Pruning knives, of which Fig. 120 gives an excellent pattern, may be used with stems up to 1½ inches thick, and shears (Figs. 114 and 115) with stems up to ¾ inch thick. It is superfluous to add that tools in use should always be sharp enough to easily cut one's finger, and for this reason they should never be struck into the earth, and a grind or whet stone should invariably accompany the workmen out into the forest.

THE ACTUAL CUTTING. The felling of a tree and the shaping of the stool should never, if it can be helped, be two distinct operations, but every stroke of the axe, hatchet or bill-book, intended for bringing down the tree, should also contribute towards shaping the stool, and *vice versâ*. This recommendation is especially important in India, where every woodcutter, unless specially restrained, will first fell the tree high above the ground, and only then think of cutting back the stump and shaping the stool, so that if the stem is at all thick, he takes at least thrice as much time as he would do if he combined both objects into a single operation. Cutting as low as is required for coppice will be found a little irksome at the commencement, but untrained men will soon get into the way of working properly, and an ordinarily skilful man will accomplish the double work almost as quickly as if he had nothing more to do than to fell the tree.

In finally trimming off any unevenness or irregularity in the stool, the blows should always be delivered from outside inwards, inclined at an angle of from 10 to 15 degrees with the tangent to the circumference at the point in question; otherwise either the stool will split or the work progress slowly and the tool be quickly blunted.

In whatever way the work is done, every endeavour should be made not to split the stool or to separate the bark from the wood. A split stool dries up quickly and decays more rapidly than a whole one, and wherever the bark separates from the wood, the dormant buds get broken off or killed, rain and dew water collects in the crevice and decomposition progresses rapidly downwards along the cambium. To minimise the shaking of the roots, small stems should be cut through in as few sharp blows as possible, and

to prevent their being split, they should be supported, on the side opposite to that on which the blows are delivered, with a portable block of wood pressed up against them. For this purpose a tool shaped something like a tent mallet (Fig. 121) will be found very convenient.

Stools felled flush with the ground should at once be covered up by drawing the soil and dead leaves over them. This protects them from the sun and, to a certain extent, also from decomposition. When the stools are cut inside the ground or completely stubbed out, good soil should be placed immediately over the cut sections and the rest of the hole filled up with earth free from wood chips, which would only attract insects and induce rot by their decomposition.

It is obvious that the coupe should be completely cleared of fallen produce before the buds begin to expand preliminary to the appearance of the shoots.

8. *Season for cutting.*

Coppice grown for bark must necessarily be cut during the first burst of vegetative activity, as it is only then that the bark can be stripped off without being injured; and stems for wattling and wickerwork must obviously be cut before they are fully lignified, that is to say, soon after the first half of the season of vegetation. Otherwise, the great rule is never to exploit outside the season of vegetative repose, during which the trees possess most buds and contain the maximum quantity of reserve material. The very best time for cutting is the week or two preceding the re-awakening of vegetation, for the cambium, being then gorged with formative sap and released from pressure at the section of the stool, at once forms a strong cementing callus between the bark and wood and effectually prevents their subsequent separation. And the worst possible time is when the new foliage is completely out, as all the reserve food has by that time been exhausted. In any case, as short a time as possible should intervene between the commencement of operations and the swelling up of the buds, and work should be stopped as soon as the sap begins to rise and cut surfaces *weep* or *bleed* profusely.

Where spring brings out the new year's shoots, the time for felling extends from the beginning of December to the beginning or end of March. But where several days of continuous frost prevail in winter, the exploitation must necessarily be put off until the season of frosts is over; if the cambium is frozen at the time of

the cutting, the blows of the woodman's tools must destroy the connection between the bark and wood, and if the frost occurs afterwards, the expansion and solidfication of the cambium followed by liquefying thaw must equally cause a separation. No work is of course possible in snow.

When vegetative activity is called forth anew by the summer rains, only night frosts can occur and the coppicing may go on uninterruptedly from December to May. Not unfrequently there may be occasional falls of rain, in the period from Christmas to April, heavy enough to provoke the appearance of shoots on stools that have already been cut; but this circumstance need not interfere with the progress of the work, only the produce should be cleared out as fast as it is cut.

Within the total period suited for coppice operations in the given case, the work must of course be undertaken when labour is available in sufficient abundance.

9. *Location of the coupes.*

The most fruitful sources of injury to stool-shoots are violent or very cold or hot or dry winds, frosts, excessive insolation and export operations.

Winds are to be feared chiefly on account of their violence, which is increased by accompanying rain; the rain weights the shoots and to the rush of the wind is added the impetus of the rain drops, and the shoots are either broken off at their insertion or bent and distorted and their upward growth arrested. Very hot or very cold winds are dangerous when they blow before the shoots are thoroughly lignified. To secure protection against a dangerous wind the coupes should be long and narrow, run at right angles to it, and follow one another in the successive order of their dates in the direction from which it comes, so that there may always be untouched forest between it and the young coppice and it may blow over the shortest dimension of the coupes, and thus be unable to get down as low as the new shoots.

The best protection against frost and excessive insolation also is to narrow down the coupes. It may even be found necessary to keep standing forest for several years on both sides of every coupe and in that case the order of the coupes will be the same as that described on p. 353, para. 3, and their width may have to be reduced to 100 feet and even less.

Narrowing the coupes will also serve to diminish the damage caused by felling and export operations; but a further measure is always indispensable, and that is to make every coupe abut on a road, so that produce may never have to be carried through adjoining standing forest. Straight lines for boundaries, being the shortest lines, will also help to lessen the damage along the edges of the bordering forest.

Lastly, narrow coupes will also check, to a certain extent, the growth of weeds, and, at any rate, prevent the soil from deteriorating rapidly and diminish any tendency to waterlogging during the heavy rains.

10. *The presence of stores.*

Against all the injurious influences of weather and soil referred to above the preservation of stores affords considerable protection, which can, however, never be as effective as lateral protection on narrow lines. Moreover stores naturally often injure the new regrowth in their immediate vicinity by their cover and stronger and large root-apparatus. Nevertheless the presence of a few scattered stores, from 10 to 20 and even 30 to the acre, according to the height and spread of their crowns and the unfavourable character of prevailing conditions, will allow of the doubling and even trebling of the width of the coupe without exceeding the limits of safety. It is necessary to add here, in respect of the influence of stores on the under-growth, that in our climate of extremes, contrary to what happens in the temperate countries of Europe, the sum total of good often outweighs that of evil.

To save damage, stores are exploited simultaneously with the rest of the stock; but if the rotation is long, dead, dying or deteriorating trees should be utilised at once, if they are not to be kept until they become quite worthless.

The rôle that stores play, in replenishing the coppice by means of the seed they shed, belongs to the subject of Section VI.

SECTION II.

Regeneration by root suckers.

We will consider this subject under the same main heads as the preceding.

1. *Influence of species, soil and climate.*

This influence has been studied on pp. 77-78, to which the student is referred.

2. *Influence of the age of the stems cut back.*

In reference to this the student should read Condition XV, p. 91-92. He will there see that trees generally continue to throw up root-suckers long after they have ceased to be able to produce stool-shoots.

3. *Healthiness and soundness of the parent tree.*

Provided the tree is neither in its decline nor half-dead nor in full decay, suckers will always be produced; and, indeed, as often said before, a certain amount of want of vigour increases the tendency of a tree to develop them, although there can be no doubt that a strong healthy tree will, when cut down, throw up stronger, if not more numerous, suckers than a weak tree similarly treated. Local decomposition of the roots is not necessarily opposed to the production of an abundant crop of healthy suckers, unless of course the rottenness is due to fungoid disease, which we know is contagious.

4. *Duration of the sucker-producing faculty, counting from the appearance of the original seedling-tree.*

We have no data to determine the relation this period bears to the natural longevity of the species concerned, but it is probable that it is more prolonged. In the case of sissu, we know that this faculty is retained for several centuries, for on no other hypothesis can be explained the presence of that species (which can reproduce itself from seed only on flooded land) on flat ground several hundred feet above the nearest stream and at least two miles away from the main drainage line of the stream basin, and which ground has certainly never once been under flood during the last two centuries.

5. *Manner of cutting.*

If the trees are still young enough to grow up again from the stool, it is evident that unless the stool is grubbed out or cut below the level of the lowest dormant buds, a very large proportion of the reserve food will be used up in the formation of stool-shoots, thus reducing by so much the number and vigour of the root-suckers produced. If simply cutting down the trees has not the effect either of producing a sufficient number of suckers or of getting them to come up over a sufficiently wide area round each tree, the roots in the ground should be wounded or broken by

running a strong plough through the soil or by driving picks or grubbing axes into it at various points. If necessary, roots may be exposed and wounded and then covered up again with good soft soil. As the development of suckers requires a considerable amount of root-aëration, very often, especially in heavily grazed forest, it will be found that it is the hardness of the soil at the surface that interferes with successful reproduction; in that case, breaking up this superficial crust may be the only measure required.

6. *Season for cutting.*

Here too the best time for felling the trees is the season of vegetative repose. But, contrary to what we have seen obtains in regard to exploitation for stool shoots, the abundance and vigour of the sucker reproduction will be greater, the earlier in that season the felling takes place, for the longer the time elapsing between the removal of the aërial portion of a tree and the actual springing up of the suckers is, the greater will be the number of new adventitious buds able to form on the roots. And the most favourable moment for felling will generally occur immediately after the cessation of vegetative activity, while the soil is still warm and moist enough for the necessary chemical changes, resulting in the formation of new buds, to take place. Nevertheless, if the season of repose is very long and there is reason to fear that severe protracted drought will kill many of the roots, the felling must be delayed until near the end of the season.

7. *The location of the coupes and the presence of stores.*

The remarks made under these two heads in the preceding Section hold good here without any modification.

SECTION III.

Comparative value of stool shoots and root suckers.

In the first place, suckers may be produced from almost any point of the area within which the roots of the parent tree have spread; whereas stool shoots, it is superfluous to say, cannot, at the outside, stand more than a foot or so further apart from one another than the greatest basal diameter of the parent stool. Hence (1) almost every sucker produced has sufficient room to grow up into a pole,

if not into a formed tree, whereas on the very largest stool hardly half a dozen shoots can survive beyond the sapling stage; and (2) suckers can be relied upon to rapidly fill up an open forest.

In the second place, suckers, owing to their very origin, come up perfectly straight from under the ground itself, and being free to develop on every side, form concentric rings of equal thickness throughout, and thus continue to grow up straight; whereas a stool shoot, unless it originates from an adventitious bud (a comparatively rare contingency), or is the result of underground exploitation, necessarily starts horizontally and describes a more or less broad curve in assuming a vertical direction, and then the parallel growth of its sister-shoots, and especially the existence on one side of the parent stool, compels its roots to spread out in only a single direction outwards, so that the strong curve at the base of the stem is maintained almost as long as the tree lives, and that and the irregular structure of the wood renders several feet of the bole unfit for sawing.

In the third place, stool-shoots, unless they spring up on very small stools (not more than a few inches in diameter), are almost always unsound at the base; whereas trees originating as suckers are, like seedlings, generally sound right down to the crown of the roots.

In the fourth place, trees nearly always retain the power of producing suckers much beyond the age at which they cease to be able to grow up again from the stool.

In the fifth place, as suckers can come up during the existence of the parent tree, which can elaborate nearly all the nourishment they need, they require less illumination to form and live than stool shoots, and are therefore less affected by the presence of stores, which themselves may become the parents of the suckers.

We thus see that, provided they belong to economically or culturally valuable species, suckers are nearly always more desirable than stool shoots.

SECTION IV.

Regeneration by means of culms.

This method of regeneration is of course possible only with bamboos.

The bamboo seedling is a simple plant with a single stem. It then becomes a compound plant or clump by developing rhizomes, from each of which a culm is produced. For many years, while

it is establishing itself, the clump consists of mere switches; it will then suddenly send up a few culms much thicker and taller than the rest, and from that time forward the culms of each successive year will be larger than those of the preceding, until the maximum size consistent with the soil, the climate, and the species is reached. *Pari passu* with, and in proportion to, the increasing size of the culms, the width of the clump and the mass of its foliage also increase from year to year.

The age at which a clump begins to produce saleable shoots varies with the species and the soil. Grown in garden soil and watered and manured, a clump may reach this stage of growth in its third and even its the second year; out in the forest *Dendrocalamus strictus* certainly takes *at least* 10 years to do so. As the natural term of life of a clump, according to the species, probably varies in round figures from 20 to 50 years, *it is obvious that for many years of its existence it is not workable.*

A culm accomplishes the whole of its growth in height and thickness in the first few weeks after it comes out of the ground, and before it has developed any very appreciable quantity of foliage of its own. Whence does it obtain the large amount of material necessary for its formation? It does certainly get all the reserve food stored up in the parent rhizome and it assimilates some itself; but the former quantity is little enough, and the latter cannot be very much more, considering the almost total absence of foliage while this growth is taking place. The only explanation left is that the very large balance comes from its fully developed sister culms. That this is the fact is amply proved by numerous experiments. If the whole of a clump in full production is cut back, even at a season when the rhizomes contain their maximum amount of reserve material, the new growth will consist exclusively of switches, and will continue so for several years until the clump is again strong enough to spare formative material for the production of large new culms. The falling off in production is more conspicuous, the closer to the ground the clump is cut away, proving that the reserve matter in high-cut stumps and the new food elaborated by the leafy branches they can develop from their lower nodes contribute a not inconsiderable quota towards the formation of new shoots. As is to be expected, the thick culms assume the largest share in the nourishment of the new shoots. This is easily proved. Cut away all the thick culms by the base leaving only the thin flexible shoots, the new growth will again be

merely switchy. Then, on the other hand, cut away everything except one or two of the large shoots that are in full leaf, or except the lower four or five internodes of the thick culms, and in the next season's growth there will still be found one or more thick shoots. The obvious conclusion from what precedes is that *in exploiting a bamboo clump all the large shoots should not be cut away, and those which are removed should generally not be cut below the third or fourth knot.*

During its first year a culm develops few branches, and most of these come out only after it has attained its full height and do not put forth their full complement of leaves. It is only at the end of its second season that it becomes completely branched and possesses its full quantum of foliage. Thus during its first season a culm grows and lives mainly at the expense of older sister culms, is full of reserve material, and is deficient in lignification, so that if cut then, it would be weak and brittle, would shrink considerably in seasoning, and would at once become a prey to insects, fungi and decomposition. In its second season, what food it assimilates is mostly required for its own further development, and it is still insufficiently lignified ; so that it is only in its third season that it really begins unselfishly to contribute towards the maintenance and growth of the joint community—the parent clump. Hence, *in the interests of both the forester and the consumer, no culm ought, strictly speaking, to be cut before the end of its third season, when it* is *just over two years old and has its full quantum of branches and foliage.*

In a complete crop, each individual tree and clump can occupy no more then its allotted space. Now the maximum vigour displayed by a bamboo clump and the culms that come up in it from year to year is attained only when every portion of the soil in which the clump is standing has begun to be fully utilised and the individual culms stand so close to one another that they impede new production. Until this stage is reached, the balance of soil and air-space still remaining unutilised enables the clump to extend itself and every succeeding year's culms to be larger on the average than those of preceding years, exactly as happens in the case of over-cut clumps when they are given rest. After this, further useful growth is impossible, unless some of the culms die or are removed in proportion to the possible sum of new production each year. Hence the following grand rule :—*Work a clump sparingly until it has attained its maximum development, which*

will be recognised by the average thickness of the culms of successive years having ceased to increase; and when this maximum has been reached, then take out fearlessly every year as many shoots as can be replaced by the subsequent season's growth. To take out less would be to uselessly sacrifice every year an amount of production equal to the defect of the quantity cut below the possible annual production. If the annual production or the average size of the shoots is found to diminish, and the falling off cannot to be traced to disease or unfavourable seasons, it is a proof that you are overcutting and the fellings must be proportionately reduced.

Very often, especially in inferior soils, crooked, deformed and stunted culms appear, which find little or no sale. If they interfere with the exploitation of the clump or the production of new and better shoots, they should be cleared away at once; otherwise they should be kept until they cease to be necessary for the progressive growth of the clump. In unfertile soils there is a tendency to the production of very short rhizomes, which results in the culms coming up in a closely packed mass and finding little room for development or drawing nourishment. The only remedy to adopt in this case seems to us to be to take out a few of the weakest or most crooked stems and to break off each year, as soon as they show themselves above ground, some of the latest shoots, which, by reason of their very lateness, are generally the least promising of the season's production.

In exploiting a clump it will often be found that certain culms, which must be cut, either cannot be got at or cannot be pulled out of the clump owing to some others being in the way. Obviously the obstruction must be removed, but in doing so, great care should be taken that the number cut out for this purpose is as small as possible and includes the least valuable of the clump. Sometimes the mere trimming away of a side-branch will suffice.

So much depends on the way in which bamboo clumps are exploited, and the work itself requires so much skill and training, that only experienced and thoroughly trustworthy cutters should be employed. Men settled on the borders of the forest and having a real stake in its welfare, on account of its regularly furnishing them with remunerative work during the slack field season, are the very best to have, even at the cost of higher wages. The restrictions with regard to the age of the culms to be cut are so difficult to enforce, that a very common plan followed is to divide the forest into two or more coupes and to work these in succession each year. The

result has not, however, hitherto been an unqualified success, for, during the year of work the clumps get overcut and either never have time to recover before they are similarly treated again or there is much loss of production while they are recovering.

For basket ware the soft, flexible, imperfectly lignified first season's shoots are generally the best, and the clumps must to a certain extent be sacrificed in order to supply such stems; but in that case an equal number of old stems, which would otherwise be cut, must be preserved as a set off.

SECTION V.

Pollarding.

Pollarding can be considered only by courtesy as a mode of reproduction, for by it new individual trees are not produced, but merely a new crop of branches, which never cease to remain a part of the crown of the original parent stem.

1. *Formation and exploitation of pollards.*

A pollard may be formed by taking off the entire crown of a tree or only the leafy portion of the larger branches. As the procedure is the same in both cases, we will consider only the first.

When a tree is decapitated, new shoots generally spring up at various points along the whole length of the stem, but they are most numerous and strongest near the extremity of the stump. In forming a pollard, these branches alone should be preserved, the rest being broken or pruned off. The height at which the tree should be headed down will depend on the object of the pollarding. At the first exploitation the shoots are either cut away close to the trunk or a foot or two away from it. The result of the former method of exploitation, several times repeated, is the formation of a thick knotty head at the extremity of the trunk, rich in dormant buds (Fig. 122). In the latter method, the new shoots come up on these stumps of branches, and the succeeding exploitations differ from the first in that the new shoots are cut off flush with the parent branch and the pollard then assumes the appearance shown in Fig. 123. This second method of pollarding is the better one, as it gives the shoots a broad base from which to spring up, and thus prevents overcrowding, enables them to grow up more rapidly, and facilitates their exploitation. In either case, the system of removing the shoots at their point of insertion cannot be continued indefinitely, as the head of the trunk or the stumps of the branches, as the case may be, ultimately become extremely knotty and covered with thick bark, whereby their reproductive power is very

considerably reduced. When this stage is reached, the larger shoots should be cut off some distance above their point of insertion, as in the original second mode of exploitation, and new parent stumps formed.

At each exploitation the entire poll may be removed or only a selected number of shoots. As far as the pollarding is concerned, it is of no consequence whatsoever which plan is followed, provided the cutting does not take place during the season of vegetation, in which case of course some shoots *must* be left in order to elaborate enough reserve food for the following season's growth. The complete clearing of the poll is obviously less troublesome, and is most easily effected with a light axe or bill hook. For the removal of selected shoots not more than an inch thick strong shears (Fig. 115 and 116) constitute the best tool; for larger shoots a pruning bill should be used.

The exploitation may be annual or come round at intervals of two or more years, according to the size of shoots required and the object of the pollarding. Thus if an abundant supply of tender succulent leaves is required, the exploitation ought to be annual or, at the outside, biennial. So again, if various sizes of shoots are required, a complete clearing may be made at regular intervals of several years, the intermediate exploitations being only partial.

2. *Value and employment of the method.*

As said before, pollarding is not a mode of reproduction, but a definite method of exploitation. Its adoption is often necessary because no other mode of regeneration or exploitation would fulfil the object required, and it furnishes much better shoots for basket work than can be obtained by any other method. Owing to the great number of shoots growing together on one and the same stump, they are thinner, longer between the nodes, and less well lignified, and, therefore, more flexible than shoots springing up on stools and roots. The very much brighter illumination enjoyed by the elevated mass of shoots forming the pollard enables it to produce much more leaf and wood, during the first few years at least, than a clump of shoots growing up on a stool of no greater diameter than the stem of the pollard. It only remains to add that pollarding is hardly suited for the production of timber, although the stump may yield a short log of thoroughly well lignified wood and some of the shoots may attain the dimensions of small poles at a comparatively early age.

Ordinarily pollarding will be adopted in the following cases:—

(1.) In large wastes, where pasturage is the main object and tree growth is maintained principally to secure a large and continuous supply of wholesome grass and leaf-fodder. The pollards are always able to shade the ground, are more easily exploited for leaves than unmutilated trees, yield a larger supply of fodder than stool-shoots, and are never liable to be browsed upon like these last.

(2) In plantations supplying material for wattling and basket ware.

(3) In plantations of mulberry, &c. made for the feeding of silk worms. By pollarding we obtain the largest outturn possible of tender juicy leaves, which are safe from the ravages of deer and cattle. Here evidently the exploitation should be annual and partial.

(4) In fields, where the crops require to be sheltered and leaves and twigs are wanted for manure and fodder or for mixing with stored seed. In this case, the trees should be such as are in full leaf in the cold and hot seasons and do not hurt the crops by their poisonous properties or their root system. The stems will supply the former with firewood and small timber. But for the purpose here discussed trees, which, with the exception of a tuft of leaves at the top, are kept constantly pruned, are much more desirable. Such trees hurt the crops less owing to their insignificant shade and drip, their much narrower and less dense spread of roots, and the greater dispersion of their dead leaves; and they produce larger and sounder timber, which is usually prettily mottled in species possessing a heart-wood.

(5) In periodically flooded land, where stool-shoots would get broken or killed, or even come up with difficulty (see p. 403, para. 2).

SECTION VI.

Maintenance of a sufficiency of coppicing stock.

Owing to the advancing age of the original parent stock, or to bad cutting, or to employing too long a rotation, or to floods, or to frost and other destructive weather influences, &c., the trees at various points may cease to be able to coppice or may be able to produce only a very weak regrowth. At such points the stock must obviously be renewed by means of seedlings.

RHIZOMES.—In the case of bamboos this loss of coppicing power does not take place partially and locally, but occurs all at once at

the final gregarious seeding, when the entire original crop dies and the ground gets profusely and successfully sown naturally. But although there is no delay in the appearance of the new generation, the young crop can yield no marketable produce for a considerable number of years. Hence it is advisable once for all to artificially replace the clumps that die out sporadically, and also those that have become weak or have been badly damaged or are not thriving. After the lapse of one generation or so there will be numerous clumps of different ages and self-sown productive ones will never be wanting.

POLLARDS.—As regards pollards, since they are seldom kept long enough to be able to seed, their replacement must necessarily be effected artificially as they individually die off or become too weak to be preserved.

COPPICE OF STOOL-SHOOTS AND ROOT-SUCKERS.—If there are no stores, seeding will be uncertain, or at any rate far too rare and ineffective to be depended on. Hence the renewal of the coppicing stock will nearly always necessitate recourse to artificial means. Sowings progress so slowly, that, to have any success at all, they would have to be made many years previous to the coppice exploitation; but at that early age a copse is generally so dense, that the seedlings would seldom survive under the heavy cover. Hence planting will be the rule. According to the circumstances of the case, either large schooled seedlings will be put down immediately *after* the exploitation and at once headed down, or small seedlings will be planted one or two years *before* the exploitation, the forest, if necessary, being sufficiently thinned immediately overhead. In the latter case, the seedlings will not be headed down, but will be cut back with the coppice. In either case, the regrowth from the seedlings will generallly have to be protected during the whole of the ensuing rotation against suppression, and it will be only at the beginning of the second rotation that they will form an integral part of the coppice.

In the case of a stored copse the end desired is attained either by self-sowing *after* the coppice exploitation, or, that failing, by the use of large or middle-sized schooled transplants immediately *after* that exploitation or of small seedlings one or two years *previously*. For self-sowing, a sufficient number of healthy large-crowned trees should be reserved, even if they have ceased to make any further useful increment. The growing individuals from among these trees will be retained as stores throughout the new

rotation, while the rest will be removed at the end of one or two years, during which the sowing, if is to succeed at all, must take place. Owing to the usual closeness of the undergrowth, any seedlings that may come up at any time afterwards, before the leaf-canopy again becomes open enough just before the next exploitation, would generally be at once suppressed. Those young seedlings, which do come up in time, will have to be specially protected against suppression. The planting will be effected as in the case of simple coppice, but the conditions will be more favourable here, by reason of the longer rotations adopted for stored coppice and, therefore, of the more open condition of the underwood near the epoch of its exploitation. A special instance, peculiar to stored coppice, of planting *after* the exploitation requires separate notice. As a rule, no seedlings will be found under the parent stores, and the gaps produced by the removal of these latter may have to be planted up. The seedlings used must necessarily be very large, the surrounding regrowth being already from one to two years old. On this account such work is generally very expensive and should be restricted within very narrow limits, save when the species thus propagated commands a very high price and grows well in the locality.

In all the various cases referred to here, seedlings coming up in small groups have the best chance of surviving and fulfilling the object for which they are wanted.

In bare exposed places it may be found useful to get up early some sort of temporary shelter by putting down cuttings in the shape of posts. In very wet land also cuttings may prove better than seedling transplants.

CHAPTER IX.

THE THREE GREAT SYSTEMS OF REGENERATION COMPARED.

We will now pass in rapid review the comparative merits and demerits of artificial regeneration, of natural regeneration by seed, and of regeneration by coppice. The comparison must necessarily be altogether general, without any reference to the various special methods comprised under each system, the advantages and disadvantages and the conditions for the employment of which methods have already been studied in detail.

In connection with this comparison one important fact must not be lost sight of. Although artificial regeneration may be effected under a more or less complete leaf-canopy as well as out in the open, nevertheless in the latter case it loses to a very great extent its distinctive character, since self-sown seedlings usually come up at the same time and form an integral part of the new crop. Hence in the following review artificial regeneration will be generally considered as occurring out in the open.

Another important point to remember is that regeneration by coppice is in itself only a secondary or derived system, for it presupposes the creation of coppicing stock by some method of regeneration by seed.

Artificial Regeneration.	*Natural Regeneration by Seed.*	*Regeneration by Coppice.*
1. Possible with all species.	Possible with all species.	Practicable only with certain species, although these include almost all we have.
2. Not dependent on the presence of parent trees; therefore possible in complete blanks of any magnitude.	Entirely dependent on the immediate presence or at least neigbourhood of seed-bearing individuals; hence impossible in blanks of any extent.	At the utmost, possible only within the spread of the roots of the parent trees, which must also be young enough to coppice; hence less far-reaching even than natural regeneration by seed.

Artificial Regeneration.	*Natural Regeneration by Seed.*	*Regeneration by Coppice.*
3. Not dependent on local seeding or even on seed being procurable in the given year.	Entirely dependent on seed years.	Totally independent of any seeding at all.
4. Dependent on a sufficient rainfall and on a generally favourable season, or on irrigation.	Like artificial regeneration.	Possible in the most unfavourable years.
5. Generation can follow generation without any blank interval; but there is always a period of waiting, while the young crop is establishing itself.	The constitution of the new generation is always a gradual process, being the accumulated results of several years' work, and often even of several years' seed-fall.	Regeneration is the immediate consequence of a single clear-felling, and the new crop may be said to be established the very first year.
6. Completeness of the new generation mathemetically regulated.	Completeness of the new generation always uncertain.	Completeness of the new generation exactly anticipated, being at least equal to that of the parent crop, and, if there is room for spreading, always greater.
7. Hence possibility of organising annually recurring work of a single kind, and of making the forest as regular as possible.	Work in any year depends on the characteristics of the season, and hence the annual operations cannot be prescribed in detail beforehand, but must	More effective than even artificial regeneration, thanks to (4) and (5).

	vary from year to year with the abundance and effectiveness of the seeding. Hence also the impossibility of constituting a strictly regular forest.	
8. Hence great simplicity of work—generally a single clear-felling immediately followed by sowing or planting.	Work complicated by the generally numerous fellings, differing among themselves according to the condition of the parent crop and the success of the seeding, and depending on so many contingencies that have to be constantly watched; also by the fact that the annual yield has to be made up not only from different classes of fellings, but from several separate areas.	Extreme simplicity of work—only a single clear felling.
9. Hence all the work of any year can be concentrated at a single point over a comparatively small area, thus making execution and control easier and more effective, felling, conversion and export more convenient and cheaper, and sales readier and more remunerative.	Owing to its dispersion and complexity, work is slow and tedious and difficult to organise and control, and the net value of the produce of the fellings is thereby unfavourably affected.	Work being even simpler and equally concentrated, the same advantages are secured as in artificial regeneration.

Artificial Regeneration.	*Natural Regeneration by Seed.*	*Regeneration by Coppice.*
10. Hence calls for only a moderate amount of skill on the part of the forester, if we except the case of an originally blank area, which indeed, as said above, could be stocked with forest under no other system.	Jardinage excluded, calls for a very high degree of technical skill and *savoir faire.*	The wholesale style of felling, which is itself the immediate cause of the regeneration, calls for little exercise of technical skill and judgment.
11. The plants being originally so spaced as not to interfere with each other, and coming up, as they do, in more or less prepared soil, enjoy an unchecked development from the very commencement. This is true even of a crop introduced under cover, for the whole area being sown or planted up in a single operation, the cover is removed before it can do any harm even to individual plants. The annual rate of growth is thus pretty steady and is very high. But, on the other hand, the wider spacing of the stems and their generally equal height and vigour, prevent the trees from being drawn up as high as they would be, if the stock were denser and there were neighbours to constantly force them up. But as a	In the case of every crop there is very considerable loss of production, owing to the protracted regeneration and the prolongation, by the cover overhead, of the seedling and early sapling stages. Moreover parent or nurse trees have not unfrequently to be kept in the interests of the new crop, long after they have ceased to make any useful growth. But on the other hand, if the seedlings are kept back by the parent crop, the trees composing this latter, being early forced by the preparatory and other regeneration fellings, expand rapidly, when every cubic foot of added timber means a proportionately large addition to the value of the tree, and may thus more than compensate for the	Coppice at first grows very much faster than seedlings or any kind of transplants, both *per se,* and on account of the comparatively wide intervals between the parent stools, &c.; and it is cut before the growth becomes slow. Hence, considering only the amount of production, irrespective of the class of wood or timber obtained, coppice yields the largest outturn per acre per annum.

compensating circumstance, the trees attain a large girth early, and therefore become exploitable long before self-sown trees can. Thus the yield of an artificially-raised crop is generally larger than that of a self-sown one.	obstructed development of the tiny seedlings. But this will happen only under exceptionally favourable conditions of climate and soil, and, as a rule, the annual yield of a self-sown crop will be less than that of an artificially raised one, especially one that has been planted.	
12. Owing to the rapid growth explained under (11), artificially-raised crops begin to give marketable produce earlier than self-sown ones, but not so early as coppice.	See under artificial regeneration.	Yields marketable produce very much earlier than even artificially-raised crops.
13. If the exploitation of an artificially-regenerated forest is economical, its constitution is very much more expensive than that of any other.	Much less expensive than artificial regeneration, even where the soil is specially prepared to receive seed.	The production of coppice rarely requires any preparation of the soil and few or no repairs. Hence, in spite of the low cutting and shaping of stools, regeneration hardly costs more than the mere felling of the trees. If we bear in mind the almost mathematical regularity of the coupes, the convenience of export, and the concentration of work, we see that the coppice system is the cheapest of all.

Artificial Regeneration.	*Natural Regeneration by Seed.*	*Regeneration by Coppice.*
14. The high cost of regeneration makes the system suitable only where quick results are desired owing to an an active demand and high prices.	As the demand for timber increases and prices rise, a point is reached after which, except in a very favourable soil and climate, natural regeneration by seed must result in a financial loss.	Suitable in any condition of the market, provided the demand includes only such classes of produce as coppice can furnish.
15. Unsuited, by reason of the uniformity of growth, for the reconstitution of mixed forests, except such as are composed of not more than two strong gregarious species which are also the most valuable.	*Par excellence* the system for reconstituting mixed forests.	More unsuited for mixed forests than even artificial regeneration, especially if one of the species produces also root suckers.
16. Owing to (3) (5) and (6), exploitations, *i.e.*, the extent of the coupes, can, within the capability of the forest, be exactly apportioned to an irregular demand fluctuating between the very widest limits.	Except in jardinage, the fellings cannot be regulated in accordance with an irregular demand, that is constantly subject to very wide and sudden fluctuations.	Gives least elasticity of all to the annual exploitations, for the smallest quantity that can be cut must be sufficient to effect the removal of every component crop before it gets beyond the coppicing age.
17. Artificial regeneration, when undertaken after a clear-felling (see introductory remarks at opening of Chapter), gives unchecked play to frost,	While securing natural regeneration by seed, the leaf-canopy can be maintained as full as we like, thus giving complete protection to the	Regeneration by coppice necessarily involves a periodically-recurring uncovering of the soil and its consequent temporary deterioration and possession

drought, insolation, winds, &c.; so that where, as over extensive regions of India, climatic extremes prevail and the soil is dry and hard during the greater part of the year and rapidly deteriorates, the system would generally be inapplicable, except at a cost that would be deterrent even with a very active demand and very high prices.

seedlings and the soil. Hence self-sowing offers the only means of regenerating forests, where prevailing conditions are exceptionally unfavourable, as over so wide an extent of India.

by masterful weeds. Hence, if the soil is very poor or naturally very dry, or the rainfall very slight and the climate otherwise very dry, or the cold very severe, or snow heavy, or the ground steep or inclined to slip, and so on, there the coppice system is to be avoided. But it is right to state that, excluding the higher and inner Himalayas, coppice in India grows up at such a pace that its inferiority to self-sown high forest in respect of the conditions here discussed is not by any means so marked as in Europe.

18. Thanks to the rapid growth of the plants, weeds can be early suppressed.

The slow growth of the seedlings in blanks and in clear fellings renders the suppression of weeds difficult.

Weeds suppressed more quickly, than in any other system of regeneration, in which a clear felling is made.

19. The warm, open, loosened soil and the concentration in one place of an enormous quantity of food in the shape of plants of more or less the same species and condition of growth, favours the multiplication of destructive insects.

The multiplication of destructive insects kept down by the very opposite conditions to what exist in an artificially raised crop.

In respect of ravages by insects stands midway between the two seed systems—a *loosened* soil is wanting, except when the trees are cut inside the ground, and the leaf-canopy is rapidly reformed.

Artificial Regeneration.	*Natural Regeneration by Seed.*	*Regeneration by Coppice.*
20. Can be undertaken, as sowing or year-old planting, under more or less complete cover.	Can do with still less illumination than artificial regeneration, since the requirements of the slow-growing self-sown seedlings are obviously comparatively insignificant.	Impossible unless a considerable amount of direct sunlight reaches the ground.
21. Owing to its rapid development, the forest reaches early a stage of growth at which the equality of height of the trees prevents the removal of certain from among them for the expansion of the rest, without opening out the leaf-canopy too much and bringing about a deterioration of the soil. At this stage, the crop, not being fit to be thinned, although unable to grow without being thinned out, *must* be felled. Hence comparatively short rotations.	The unequal growth of the individual trees permits of the maintenance of a much larger number of stems than in an artificially-raised crop of the same age, so that the forward trees can be constantly given more growing room until they have nearly attained their largest dimensions while still remaining sound, and this without ever opening out the leaf-canopy to any dangerous extent. Hence possibility of very long rotations.	Requires by very much the shortest rotation of the three systems, owing to the limited age up to which trees can generally coppice; to the immediate appearance of a new generation, to the great early rapidity of growth, and to the usually increasing unsoundness of the stems.
22. The plants being all of one and the same age and, therefore, of nearly the same stature and vigour, and necessarily standing apart from one another, the individual trees are unable to draw one another up to the full height which their species is capable of attaining, and	The plants come up close together and grow up some faster than others, thereby constantly pushing one another up, until the more forward ones have reached the maximum height attainable by their species. They thus furnish long, straight, clean-fibred,	The very short rotations necessarily prevent the production of more than a very moderate quantity of timber. This timber is furnished by the stores, which, towering above the undergrowth, enjoy an isolated existence from the close of the very first rotation, and it is

the boles remain short and become knotty from epicorms, and often also misshapen. In addition to this, the shortness of the rotations prevents the attainment of any considerable girth. Thus artificial regeneration gives timber of only moderate dimensions and quality, and a larger proportion of fuel than natural regeneration by seed.

more or less cylindrical timber, which the long rotations permit to acquire the largest girth possible under the prevailing conditions of soil and climate. Hence if we wish to obtain the most considerable quantity of the best and largest timber, we will adopt natural regeneration by seed. And in respect of all classes of wood generally, the very long rotations result in the largest possible accumulation of standing produce and, therefore, in the largest measure of annual enjoyment.

therefore tougher, harder, stronger, and more durable than timber otherwise grown. But as stores generally begin to decay early at the base, they are usually felled before they can attain the largest dimensions attainable by their species. Moreover, the isolation in which they develop, dwarfs them and renders their boles even shorter and more knotty and mis-shappen than those of trees grown in artificially-raised crops. If only firewood is wanted, then other circumstances not being prohibitive, the coppice régime is to be preferred owing to the greater rapidity and certainty of regeneration, the early realisation of marketable produce, the easiness and extreme regularity of work, the large annual increment of production, and the very low cost.

The preceding comparative review of the three great systems of regeneration shows that no one of the three can be said to be the best in every case. It may happen that in even one and the same crop the first gives the best results at one point, the second at another, and the third at a third, so that while some one of them must be generally adopted, the results would be incomplete without the supplementary help of one or both of the rest. Hence no hard and fast rule can be laid down as to when one system should be employed and when another, and the best plan will always be to so combine any two or all three of them, as to secure to the fullest extent the respective advantages offered by each, while doing away with, or at least minimising, their attendant disadvantages. We have already seen instances of such combinations under the uniform method (pp. 381-3), and also in describing coppice regeneration (pp. 416-418). A further instance would be the partial artificial restocking, with some hardy species, of more or less exposed ground under old open forest, in order to facilitate natural sowing when the seed felling falls due. For the benefit of the student we may summarise the various possible combinations as follows :—

I. *Artificial regeneration with natural regeneration by seed,* in which case the former may (i) precede or (ii) follow or (iii) be simultaneous with, the latter.

II. *Artificial regeneration with coppice,* of which combination there will be two separate cases according as stores are or are not kept.

III. *Natural regeneration by seed with coppice.* If the former is the main system adopted, then coppicing is resorted to in order to restore damaged seedlings and to keep back inferior growth (pp. 381-2) ; if it is the coppice system that is used, then self-sown seedlings will be sought and utilised to maintain the coppice-producing stock in its fullest abundance and vigour (pp. 417-8).

IV. *Combination of all three systems.* Necessary only in stored coppice (for illustration see p. 418).

One great rule for general guidance can, however, always be laid down. As natural regeneration, whether by seed or by coppice, costs little or nothing at all, we should in every case, especially in a vast country like India, where we can only work on broad lines without venturing into any great detail, endeavour to make it our stand-by and have recourse to

artificial methods only as supplementary expedients, using these latter as our principal means only when the end sought cannot be attained by any other, as when extensive blanks have to be stocked or where seed-bearing trees are wanting or when the species it is intended specially to propagate cannot reproduce itself, in any thing like adequate proportions, &c. As respects natural regeneration by seed, some advance growth of the valuable species will rarely fail to make its appearance before the seed felling falls due or the crop is ripe for the axe. Often this advance growth will be all but complete, and, at the worst, it will always be abundant enough to save a considerable amount of artificial work, even when no seed felling is undertaken and direct sowing or planting at is once proceeded with.

BOOK III.

MAINTENANCE AND TREATMENT OF FORESTS.

INTRODUCTORY REMARKS.

The sylviculturist's work does not end with the creation and establishment of a forest crop; in order that the crop in question shall fulfil in the most complete manner the object of its existence, it must be constantly treated in the way that will conduce most effectively to the realisation of that object.

At the bottom of page 107 we have already enumerated the three distinct purposes, one of which at least every forest is called upon, in the economy of man and nature, to fulfil. In the immediately following pages we will confine ourselves to the case of forests grown solely for the market, omitting all reference to that of forests maintained for the landscape and only incidentally dealing with that of forests, the rôle of which is to afford protection.

The productiveness of a crop will obviously depend on five sets of circumstances, *viz.* (1) the amount of protection afforded, (2) the climate, (3) the soil, (4) the constituents of the crop, and (5) the way in which it is made or allowed to grow up. All five sets of circumstances necessarily act and react on each other, and no one of them can be considered without involving a consideration of, or reference to, the rest.

In respect of protection we will concern ourselves in this Manual only with the prevention and suppression of fire in forests, as the other branches of the subject fall under the special heads of Law, Police, Administration, Zoology and Botany.

The influence of climate on the growth of forests has been pretty fully considered in Part I at pp. 25-6, 53-61 85-6 and 89, and the extent to which climatic influences may be qualified by cover is explained at p. 9. Regarding the modifying action of forests on climate it is enough to say here, without devoting a special chapter to it, that it consists in the moderation of extremes of temperature and therefore in the narrowing of the daily and annual range, in the raising of the mean in cold and its diminution in hot localities, in increasing and maintaining atmospheric moisture and hence in increasing and prolonging dew-deposition and, in most cases, also rainfall, in tempering winds and diminishing their velocity, and, as a consequence of all this, in the prevention of sudden or wide fluctuations. This modifying action of forests will obviously be effective in proportion to their height, density and

evergreen nature.

The soil is a much more important factor in sylviculture than climate, for whereas the latter leaves us no choice at all as to the species to cultivate in any given locality, the action of man is all-powerful in most cases in extending or restricting, favouring or checking the growth of all or any of those species. The care of soils will, therefore, be briefly treated in a special Chapter after Fire-Conservancy.

The rest of the Manual will be devoted to a description of the various operations and combinations of operations by means of which the growth of a forest can be regulated so as to enable it to realise to its fullest extent the intention of its owner.

CHAPTER I.

FIRE CONSERVANCY.

The term which heads this Chapter is an unhappy one, for it means, not what it implies, but the very opposite, *viz.*, the preservation of forests from fire. But long use in official reports and professional parlance has given it the stamp of currency, and no shorter and more appropriate equivalent expression, unless indeed it be *fire prevention*, has yet been devised.

To Sir Dietrich Brandis is due the honour of having first urged, with his characteristic energy and indomitable perseverance, the necessity of taking special measures for the prevention of forest fires, and to the Central Provinces Administration is due the honour of having first adopted them and practically demonstrated the possibility of success. An historical interest will for ever attach to the name of the Bori forest, at the foot of the Pachmarhi block of the Sathpuras, where in the cold weather of 1865 the first attempt at fire conservancy was made by Lieutenant, now Lieutenant Colonel, J. C. Doveton, acting under the orders of Major Pearson the first Conservator of Forests in those Provinces. For various reasons little general interest was taken in the subject for several years, so little indeed that two successive and completely successful attempts made in Garhwal, N. W. P. by that talented officer Mr. Richard Thompson, in 1866 and 1867, were passed over without the slightest official notice having been taken of them. It was only in 1871 that measures for protecting forests against fires began to be generalised, and it was not until 1872 that they were extended to the majority of the several provinces of India.

SECTION I.

Necessity for keeping out fire.

Fires injure forests in various ways. *Firstly*, they destroy fallen seeds and, if they rise high enough, also fruit still hanging on the trees. *Secondly*, they kill all yearlings not possessing any collum buds and most of those possessing such buds; also a larger or smaller proportion of older plants, according to the amount of

combustible matter on the ground, the number of casualties being greatest if the species are coniferous. *Thirdly*, the plants, that are not killed, are thrown back in their growth, are rendered unhealthy, unsound, stunted, crooked and knotty, and become an easy prey to, and serve for the multiplication of, insects and fungi. *Fourthly*, this deterioration of individuals may, and often does, become permanent and perpetuated in the offspring, resulting in the formation of defective varieties. *Fifthly*, the production of vegetable mould is effectually prevented, the slight amount of useful mineral matter rendered immediately available in the ash being a very poor compensation for the much larger quantity of other substances dissipated, and being to a great extent blown away by the wind or washed away by the first few heavy showers of rain. *Sixthly*, the exposure of the soil, consequent on the burning of the weeds and brushwood on it and of the vegetable *débris* covering it, hardens it, dries it up quickly, produces rapid and wide fluctuations of temperature in it, makes it refractory to fertilising influences, and renders it liable to erosion or at least to the washing away of the better portions from the surface. *Seventhly*, seeds falling on such soil find a most uncongenial bed, and any seedlings that may come up are unable to extend their roots to any depth, remain ill-fed and succumb easily to drought, excessive insolation, or frost. *Eighthly*, the intense heat of the fire bakes the soil, and vitrifies the surfaces of stones and rocks and delays their disintegration and decomposition. *Ninthly*, owing to the hardening of the surface soil due to the heat and the exposure, rain water falling on it cannot penetrate it easily, and so rushes over it in a large volume, all the more rapidly because of the absence of any weeds or bushes or covering of dead leaves capable of checking it, the result being inordinately swollen rivers, which fall as suddenly as they rise. *Tenthly*, another result is that, as the water has no time to sink, in any considerable quantity, into the ground and most of it goes away at once into the rivers, the level of springs falls very low, and springs that would otherwise be abundant or permanent, become exiguous or dry up entirely. *Lastly*, the heavy floods in the rivers may cause them to erode and overflow their banks, spread devastation far and wide over the country on each side, and cut out every year a new channel for themselves. Thus fire conservancy is the very root and foundation of all forest conservancy, and is the first object of all to secure before any forestry can be attempted.

And the necessity for adopting special measures to secure protection from fire is so much the greater on account of the numerous wide-spread inducements that exist for the firing of our forests. The first and foremost of these is the interest which graziers have in obtaining a crop of green grass in the height of the hot weather, four or five weeks or even more before the beginning of the S. W. monsoon (see p. 37, para. 3.) The next is the increased facility for moving about in a burnt forest and for looking out for forest produce and game. In respect of this latter the burning of the grass and bushes reduces the amount of cover and thus also drives the animals to a few isolated spots of limited extent. Then again, firing is the easiest and cheapest means of clearing away from near cultivation low thick undergrowth giving cover to destructive animals. The reduction of cover also lessens the risk to human life from wild beasts. And so on. Besides these direct inducements to fire the undergrowth that are a perpetual menace to the safety of our forests, a very fruitful source of danger is the constitutional indifference of the millions of strolling smokers of the Indian pipe or *chilam* of earthenware or rolled up leaves, the use of which requires nothing less than a piece of burning charcoal or cowdung.

Besides preventing the dangers and disasters enumerated above, fire conservancy has the effect of reducing both the density and height, that is the actual quantity, of thegrass produced each year. New shoots come up in less abundance and grow up with less vigour on the clumps still bearing the old decomposing shoots of preceding years, and many stumps thus get gradually weaker and ultimately die. Moreover the dense matted rotting mass formed by the dead grass is very unfavourable for the production and survival of new seedlings of herbaceous species in general and of the tender single-bladed grass seedling in particular. Indeed, it is an established fact that in many cases certain species of grasses are to a great extent killed out, the survivors being generally short and wiry kinds and forming more or less isolated clumps. This diminution of the natural crop of grass is most conspicuous in dry climates, and in stony, naturally dry soils. In a moist climate and in rich moist soils it is hardly perceptible, owing probably to rapid decomposition and to the immediate washing away, by the heavy rain, of the deleterious products of decomposition.

The necessity of fire conservancy in regard to its influence on the distribution of species will at once appear from a perusal of pp. 36-42.

SECTION II.

Intensity and fierceness of forest fires.

The intensity and fierceness with which a forest fire burns depends on a combination of a great many circumstances, the principal of which are as follows:—

(1) *Density and height of the grass.* The presence of grass is the greatest obstacle there exists to the success of fire conservancy. If the grass in a forest can be suppressed or removed, the only danger left would be that of a pure leaf-fire, which would obviously be comparatively light, be a standing menace to the forest during a much shorter time of the year, and, except on a steep slope, be extremely easy to circumscribe and extinguish. In a forest fire the density of the crop of grass is of far greater consequence than its mere height. Where it grows in isolated patches, the grass generally burns with difficulty, unless there is a strong and steady breeze blowing. This is especially the case if the grass is not yet quite dry; and, under any circumstances, the flames flare up so irregularly along the advancing edge of the conflagration that the fire can usually be beaten out with ease. A thick crop of grass, although visibly green, will often burn steadily and fiercely along the whole line before a very slight breeze, and the fire may even defy any direct attempt to get it under. On the height of the grass depends, besides the total quantity of combustible matter present, also the force of the draught of air rising from below upwards. It hence influences directly the length of the tongues of flame and the height to which they can rise, and, but in an inverse ratio, also the rate of progress of the conflagration, so that if the fire becomes severer and more unapproachable with the increasing height of the grass, the rapidity with which it advances is, by way of compensation, proportionately diminished and the chances of circumscribing it are in the same measure increased. From what has just been said it must not be inferred that, because in short grass the fire does not flare up high, it cannot therefore damage the forest growth beyond a moderate distance above the ground. With the burning grass barely more than a foot high, the heat vertically over it may be intense enough to set ablaze the entire crowns of trees 80 feet and upwards in height. Another very important point to draw the attention of the student to is the rapidity with which fire spreads when the grass is short without being quite spare. Before an ordinary breeze, fire in such grass may sweep on at the rate of

3 to 4 miles an hour, and driven by a steady wind, still very far short of a gale, it may rush forward at double that speed.

(2) *Dryness of the grass.* It is evident that the more moisture there is in the grass, the greater will be the difficulty with which it will take fire, the less rapidly and less regularly will it burn, and the less heat will it give out. It is equally evident that the longer the season during which fires can occur is, the drier will generally be the grass on any particular date and the longer will it be found in a perfectly dry, and, therefore, its most highly inflammable, state. The difference in the length of the fire season in different parts of the country is very striking. In many forests in the Punjab and Central India extensive conflagrations may in any year occur as early as the beginning of October, and the season does not close until the setting in of the S. W. Monsoon rains, which event takes place in June in Central India and not until July—August in the Punjab. In many sal forests, on the other hand, fires are possible only during two or three months out of tne twelve. The length of the fire season of course depends primarily on when the grass dries up. Grass always dies down and dries up after fructification is complete. The drier and warmer the soil and climate are, the sooner do the ears ripen and the stalks dry up. But the grass may also die and dry up prematurely from the effects of frost. In either case it becomes fit to burn earlier out in the open than under the cover of trees.

(3) *Abundance of fallen leaves.* Outside the Himalayas, in forests liable to conflagrations, the climate is warm enough to cause shed leaves to fall to pieces and decompose almost in a single season, so that when such forests are continuously preserved from fire for several years, no more than the fallen leaves of a single season can accumulate to feed any fire that may occur. In the cool air of the Himalayas, on the other hand, especially in forests containing conifers, decomposition and disaggregation are so slow that the ground may be covered with the accumulated unreduced fallen leaves of several years, forming a close mass more than a foot thick, and burning like tinder, very gradually and with little or no flame. Seedlings standing in such rubbish are bound to be burned to death. As regards a pure leaf-fire generally we may say that even in a high wind and with the leaves packed loose and high, the flames will seldom rise up more than a few feet, rarely scorching the crowns of anything taller than small poles.

(4) *Size and nature of the leaves.* As just said above, some leaves, like those of conifers, take several years to decompose, and

consequently form a thick accumulation of combustible matter on the ground. Besides this, resinous leaves are obviously more highly inflammable than those that are non-resinous. Large thick fibrous leaves, like those of teak, not only form a thick loosely-packed mass, which flares up high and fiercely, but individually burn for a long time, so that they are often carried up and dropped in an ignited condition a more or less considerable distance off, sometimes as much as 100 yards and even more. And so on.

(5) *Violence and constancy of the wind.* The actual burning of the dry grass and leaves converts a mild breeze into a high wind, and a brisk wind into a gale. A steady wind drives the long tongues of flame along the ground, and creates a lateral blast of such intensity as to set fire to grass even a hundred feet beyond the visible reach of the flames.

(6) *Absence or lightness of dews.* The severest forest fire will at once of itself go out at nightfall where heavy dews are deposited. In sheltered situations, in the cold weather, dew may begin to form even before sundown and not be evaporated until past noon. In some places in India dews prevail right through the rainy season and on to the end of April and even the middle of May, and are, for many months, so heavy that the trees drip all night long and during the early morning in the same manner as after an abundant fall of rain. In other places, at the extreme end of the scale, they are never heavy and are limited, outside the rainy season, to the three or four months following the close of the S. W. Monsoon.

(7) *Heat of the sun.* Where the sun is powerful, the grass dries up early, dews are light, begin to be deposited late in the evening, are quickly evaporated, and prevail during a limited time of the year. The heat also directly assists a conflagration.

(8) *Sloping ground.* Fire naturally progresses most rapidly *up* a slope, and more rapidly the steeper the gradient is, provided of course the ground is not too steep to bear a complete crop of grass or support a thick continuous mass of dead leaves. On the other hand, burning fragments roll or slip *down* a slope, and thus aid the rapid spread of fire, as well as render its extinction on the lower side of the slope extremely difficult. On a declivity dead twigs, leaves, &c., accumulate against the upper side of the foot of the trees, and, in burning themselves, char and kill that side of the stems, the fire often working its way through far enough to bring down a tree.

(9) *Nature of the component species.* Some trees take fire, even in a green state, more easily than others; some suffer less direct damage or recover more readily and completely than others; and so on (see pp. 36—42). The resinous cones of conifers can carry down fire over a whole hillside. Hollow bamboos in combustion burst with great violence, and in Berar burning fragments, assisted no doubt by the wind, have been known to be flung to a distance of 500 yards.

(10) *Nature of the soil.* Forest fires are fiercest in a loose dry soil, and mildest in a compact or hygroscopic soil. When the soil is compact, no current of air can rise up from its interior to fan up the flames; and when the soil is moist, this current of air is so charged with steam that, if it does not put out the fire above, it at least moderates its intensity.

From the foregoing discussion it is easy to see that the danger and severity of a conflagration will be very different according to the prevailing conditions. In some forests the occurrence of fire is physically impossible; in other classes of forests large areas remain safe for several years together without any special measures of protection at all; in others again the whole area must, unless it is specially conserved, burn regularly every year; and amongst these last, different forests will require different degrees of care, vigilance, and intensity of protection. Whereas in some forests a conflagration will usually sweep over as much as 20 square miles in the 24 hours, in others, even during the driest season of the year, scarcely 5 square miles will be burnt in as many days; and indeed, in the Himalayas, an average of 100 acres burnt in 24 hours is an unusually heavy casualty. In one instance, in the Mundáli deodar forest, only 30 miles inside that range of mountains, a fire, after smouldering on for five days in a deposit of dead leaves about 2 feet thick, spread over barely half an acre of the hillside. On the other hand, in Central India, the grass standing in a continuous mass, a fire occurring in the hot weather can seldom be put out before it has extended over several thousand acres.

Hence in comparing statistics of fire conservancy in the different forest regions of India, or in drawing, from particular instances, general conclusions regarding the success or failure, adequacy or inadequacy, and cheapness or expensiveness of particular measures and methods, we cannot be too careful to make full allowance for the peculiar circumstances of each case. For in-

stance, 1,000 acres burnt in fire-conserved sal forest along the foot of the Himalayas will undoubtedly prove more inefficient protection than 10,000 acres burnt in the open low teak forests of the Central Provinces.

SECTION III.

Means of prevention.

The means for preventing fires in a forest naturally group themselves under three main heads as follows :—

I. Measures for preventing fire from entering from outside ;

II. Measures for preventing fire from spreading from one part of the forest to another; and

III. Police, and putting out conflagrations which it has not been possible to prevent.

ARTICLE 1.

PREVENTION OF ENTRANCE OF FIRE FROM OUTSIDE.

The measures for preventing the ingress of fire from outside must naturally vary with the conditions described in Section II, and with the condition of the surrounding country. If the land is cultivated right up te the edge of the forest, then it is obvious that no conflagration could possibly occur immediately outside the forest and there would be no danger to it except at the hands of incendiaries or through sheer wanton carelessness on the part of the cultivators. Again the grass outside may be browsed down so close to the ground as to leave nothing to burn. Excepting these two cases, in which an outside fire would be impossible, *fire-breaks* of some kind are absolutely necessary to effectually stop the further progress of a conflagration approaching the forest.

A fire-break, which may be either natural or artificial, or a natural one rendered more effective by the forester, may be—

(1) A stream wide enough and sufficiently free of grass and other combustible matter to prevent the passage of fire. According to the prevailing conditions the minimum width of the stream need be only a few feet or may have to be several hundred yards.

(2) A sufficiently wide belt of swampy ground, the vegetation on which can never burn.

(3) A sufficiently wide and dense belt of some evergreen shrub, like *Adhatoda Vasica*, the prickly pear, &c., which grows close enough at the base to prevent grass from springing up in its midst. An advancing conflagration will generally burn some distance

into the belt, but with constantly diminishing force until it quite goes out.

(4) A sheer cliff, the forest to be saved being on the upper side.

(5) A road. In most parts of India, however, the widest road would be too narrow to stop a fire.

(6) A close-planted belt of broad-leaved trees, which remain in full leaf throughout the season during which fires can occur. Such belts can be really effective only in the Himalayas at altitudes above 4,000 feet more or less, and perhaps in very damp climates also. Even in the south of France they fail to stop fire unless the ground below is kept clear of bushes and dead leaves. Under any circumstances, their employment cannot be generalised in India. In the first place, the species used would have to be evergreen; in the second place, the soil along by far the greater portion of the boundary of our forests would be found unsuitable for the growth of such species; and, in the third place, the cost of raising and maintaining such belts, except they were formed of valuable fruit trees, which would bear very little unless planted so far apart as to be unable to suppress a growth of grass and annual weeds, would be entirely prohibitive.

(7) Lines of sufficient width cleared of all combustible matter. The clearing may be effected either (i) by cultivating the soil and raising field crops thereon, or (ii) if possible, by allowing the grass to be browsed down to the roots, or (iii) by having the grass cut as close to the ground as possible, or (iv) by means of fire. The *first* method is of course possible only in the neighbourhood of population, where the soil is suitable for permanent cultivation and is clear of trees: it not only costs nothing, but may in most cases return some revenue, and should, therefore, be adopted wherever the required conditions exist. For the *second* method to be feasible it is necessary that all the grass should belong to fodder-yielding species and that the cattle should be sufficiently under control not to stray beyond the limits fixed for them. The system is capable of generalisation round the stone-fenced reserved forests of Ajmir and Merwara, where pastures are limited. The high cost of cutting all the grass close to the ground renders the *third* method impracticable except where the entire, or all but entire, crop is suited for haymaking or thatching, and there is a ready demand for such grass. When the village population are accustomed to lay by a store of hay for the six or eight months of the

dry season, it is often possible to have several miles of line cleared in this manner in return merely for the free gift of the grass. The *fourth* and last method is the one of most general application. Indeed, there is scarcely a single forest requiring protection from fire, in which at least nine-tenths of the lines have not to be cleared in this manner in order to secure the necessary economy of time, money and labour. A line cleared thus is called a *fire-line* or *fire-trace*. From the latter term we obtain the verb to *fire-trace* and its derivatives. Fire-tracing is an art in itself and will be treated separately in detail in Article 3.

(8) Various combinations of 1-5 and 7. The most usual will be a fire-trace flanking one side of a stream or one or both sides of a road, in order to increase the width of the fire-break to the minimum of safety, and, in the case of a road, also to isolate it from the standing grass and to prevent any risk from careless wayfarers, who often rest themselves by the side of a road or saunter along carrying a burning fire-brand or torch or a lit hubble-bubble. For the sake of economy the fire-trace flanking a stream need not always remain on one and the same side of it, but may cross it at various points in order either (*a*) to keep out of a heavy growth of grass, or (*b*) to get into grass that dries up early, or (*c*) to follow easy ground, or (*d*) to take a short cut at bends of the stream and thus to reduce the amount of work to be done (Fig. 129) or (*e*) to take the line past a belt or large mass of close-grown forest or bushes into which fire cannot penetrate at the time of the fire-tracing operations, thus doing away with the necessity of clearing a *guide line* (see p. 454). In fire-tracing along one side of a road, it is obvious that the very conditions of the combination rigidly fix the side which the fire-trace should never leave.

ARTICLE 2.

Localisation of internal fires.

When a forest is large, it is always expedient and nearly always necessary to divide it into blocks completely isolated from one another, so that if a fire broke out in any one of them, it could not possibly spread into those adjoining.

This division can only be effected by means of a system of fire-breaks similar to those described in the preceding Article. But whereas, in devising a system of fire-breaks to exclude fire coming from outside, the boundary line cannot obviously be

deviated from, in the present case the forester is at full liberty to choose the most economical and effective lines that offer. For instance, he will make the most of streams, water-courses and swampy places, ridges and spurs, roads existing and to be made whether for traffic or for inspection, open grasslands, belts of evergreen species and of others facilitating fire-tracing or opposing any kind of obstacle to the progress of fire. The crest of a ridge or spur, if it is regular enough to be everywhere easily accessible, offers the safest alignment of all for a fire-break, for fire could not possibly be blown over across it to the other face of the hill, however rapidly a conflagration rushed up towards it. And here it may be necessary to warn the student against running fire-breaks along the face of a hill or along the bottom of a narrow ravine or valley. It is needless to say that cliffs should generally be avoided, for if on the one hand, fire could not possibly climb up from below upwards, on the other hand, there would always be the risk of burning brands and other fragments being blown down from above, unless a very broad fire-trace were cleared, or a sufficiently wide belt of some evergreen shrub, tree or climber grew, along the upper edge of the cliff.

Although a truism, still it is necessary to say that at no point of the length of a water-course, too narrow to serve by itself as a break, ought more than one bank to be fire-traced. As regards a road both or only one side of it should be cleared of combustible matter according as it is a frequented public thoroughfare or the traffic is light or strictly regulated; and when only one side is fire-traced, it should be that from which the wind blows. It is obvious that the more nearly perpendicular to the direction of the strongest winds a fire-break is, the broader must it be. Hence in the interests of economy, if artificial breaks are in question, they should diverge from that direction as much as the topography, system of export, the shape and lie of the forest, and other prevailing conditions will allow.

The smallness and hence the number of the fire-blocks will be directly proportionate to the value of the standing stock, to the intensity of treatment to which the forest is subjected, to the ease and inexpensiveness with which the division can be effected, to the amount of traffic passing through the forest, and to the difficulty with which, owing either to insufficiency of labour, or inaccessible ground or to the conditions described on pp. 426-9, conflagrations can be put out. The size of the blocks in different forests will

thus be very different, but as a rule it ought not to exceed 10 square miles in remote forests of no great value or 1000 acres in valuable forests on which there is an active demand. Except in small coppices, in which each annual coupe will generally form a separate block, a smaller minimum than 200 acres will seldom be required.

The width of the intervening fire-trace may be insufficient to prevent in all circumstances fire from crossing over from a burning block to the next one; and even if the width is in itself sufficient, the trace may not at the time be effective, because of fallen dead leaves strewing it or from its not yet having been completely cleared, or for any other reason. In such a contingency, if the conflagration cannot be put out before it reaches the trace, the only plan to follow is to fire the grass along the trace in the burning block, so that this fire may spread towards and meet the advancing conflagration. The lighting of such a fire is technically turned *counterfiring* and its object is to prevent the larger conflagration, with its intense heat, from attaining a too dangerous proximity to the intact block. The subject of counterfiring will be dealt with in more detail in a subsequent section.

ARTICLE. 3.

Fire Tracing.

Expressed briefly and in the most general terms, a fire-trace is cleared by cutting and sweeping away all inflammable matter from over a certain width along both of its edges, and then firing all the intervening grass and other combustible stuff, the burning being regulated and controlled by a gang of men stationed along each edge and provided with bunches of stout leafy twigs, with which the spreading flames can, when necessary, be beaten out. The two cleared lines, one along each edge of the fire-trace, which serve both as an alignment to the men and to prevent the fire from getting beyond the trace into the forest to be preserved, may appropriately be termed *guide* or *check* lines.

In fire-tracing operations it is necessary to know (1) in what direction to run the traces, (2) what width to give them, and (3) how to prepare them.

I.—Direction of a fire-trace.

The direction in which a fire-trace should run is generally fixed

for it by existing natural features or roads or the boundary it has to follow. But sometimes, as when there are no lines on the ground to determine its direction or the choice lies between two or more such lines, then full consideration, within the measure of discretion allowed by other circumstances, should be given to the quarter from which a constant wind blows. If the trace ran at right angles to the line of such a wind, its firing would become extremely difficult, if not practically impossible, for it must be remembered that the force of the wind would become more than doubled by the burning of the grass on the trace, and the violence of the fire and the length of the flames to leeward of the trace would consequently necessitate a very broad guide-line, the cost of which might be entirely prohibitive. In close-standing, fairly dry grass only four feet high the flames may, when only a stiffish breeze is blowing, reach across a guide-line 16 feet wide and set on fire the grass beyond.

It is evident that the more a fire-trace deviates from the perpendicular to the direction of a constant wind, the easier, more economical and less fraught with risk does its clearing become. But in observing this obvious rule, there is one danger that has to be avoided. It must first be clearly ascertained that the wind in question is really a constant one, and that it has no tendency to veer completely round all of a sudden. Should the wind change in this way while the trace was being fired, the flames would rush along in the direction of the unburnt length of the trace, and in a few minutes, perhaps even in a few seconds, extend so far as to get entirely out of hand and then spread away into the forest. Such an eventuality is most to be feared in dry, short wiry grass, in which the fire may travel along at the rate of four miles an hour before a very moderate wind. Hence, unless there is complete certainty that the prevailing wind is not subject to sudden changes, and there is some latitude for choice, it is always advisable to let the fire-trace make a small angle (10 to 15 deg.) with the direction in which it blows. The full force of this recommendation will be perceived when we come to treat of the method of firing traces.

II.— Width of fire-traces.

A trace may be intended to serve as a complete fire-break in itself, or its object may be simply to arrest to a certain extent the progress of a forest conflagration and to serve as a base from which to counterfire. In the first case it should be broad enough to prevent

the most violent fire from crossing it in any circumstance, in the other its width should be merely sufficient to arrest the progress of a fire at most points and to make it easy to light rapidly, and with the minimum of labour to control, a counterfire in order to meet an advancing conflagration. It is evident that all boundary traces should be of the former class, while internal ones may be either the one or the other according as the staff of watchers is or is not sufficiently numerous and well-distributed to start counterfires promptly before the conflagration to be restricted can reach the trace in question.

It may be objected that all traces without exception should be effective fire-breaks; but it must be remembered that the broader the traces are, the more expensive are they to clear, and, what is a far more important consideration, the larger is the area abstracted from protection, for as the aggregate length of internal traces in a valuable and well-exploited forest is always great, a few additional feet of width would necessarily involve a considerable addition to the area deliberately burnt. And then it must also be borne in mind that whereas we cannot rely on the grass outside the forest being saved, but must even assume that it will certainly burn right up to the boundary traces, we may consider a conflagration inside the forest as only a contingency that may not occur at all, so that internal traces of a greater width than what would suffice with counterfiring to check the spread of the conflagration would be a superfluity, involving needless expense and needless sacrifice of a portion of the standing stock.

So much being said, it may be laid down that the width of a boundary or other trace, the object of which is to effectually arrest the progress of a conflagration, will depend on the height, closeness and inflammability of the grass, the nature, abundance and size of the fallen leaves, the density of the leaf-canopy, the violence and direction of prevailing winds, the intensity of insolation, the slope of the ground, and the dryness and porous condition of the soil. To these conditions, in the case of traces requiring counterfiring, must be added the rapidity with which fire travels in the forest in question and the promptness with which counterfires can be started and run along them.

It will thus be seen that the width of a fire-trace is a figure variable not only from forest to forest, but from locality to locality of one and the same forest. In some places a width of 10 feet may suffice, whereas in others even 600 feet may not prove sufficient in all circum-

stances. Hence in each particular case the existing conditions should be fully studied and the width adapted to those conditions. A trace that is not broad enough will defeat the very object for which it was made, while one that is broader than what is necessary will be a cause of unprofitable expenditure of money and needless sacrifice of forest growth that ought to be protected. Nevertheless a small margin of safety is always permissible.

III.—Preparation of fire-traces.

In the preparation of fire-traces the following points have to be considered :—(1) width and clearing of the guide lines, (2) necessity or otherwise of clearing the traces of all woody growth, (3) season and time of day for firing and number of times to fire, and (4) the process of firing and how to conduct it.

1.—Guide-lines.

In preparing a fire-trace the main difficulty is so to control the firing as to prevent the flames from spreading beyond the trace into the areas to be preserved.

The first point to consider is whether guide lines can in any circumstance be dispensed with. One may already exist in the shape of a watercourse or road or broad well-beaten track running along one edge of the trace to be cleared; or the trace may be flanked for some distance by a belt or patch of green forest or bushes which fire cannot enter. In none of these cases is there any necessity for specially preparing a guide line, except in so far as a little partial clearing may be required at those points here and there, where these natural barriers are too narrow or covered with dry grass or otherwise insufficient to stay the progress of fire.

Occasionally in short grass and with well-trained fire-tracers, when the wind is not unfavourable and the forest to be protected lies only on one side of the trace, the burning may be effected without a check-line. This has been done under the Author's supervision in the Central Provinces, when the entire boundary trace of a forest of roughly 50 squares miles was so cleared for about Re. 1 per running mile, the daily wage of a man being 4 annas.

The exceptional cases just described being left out of account, a guide line must be cleared along one or both edges of a trace according as the fire is to be controlled and put out along a single side or along both sides of it. The former is the case when the area on the side on which the fire is allowed to spread unchecked is not to

be protected and contains no property the safety of which would be thereby endangered. When only a single guide line is employed, a serious risk is incurred for which it is necessary to be prepared. If during the firing a gale should suddenly spring up and carry the fire rapidly ahead of the burners, it is quite possible that the conflagration may be subsequently turned back, by a change in the wind, in the direction of the protected area and enter it at a point where the fire-trace has not yet been cleared. To provide against such a contingency the right season and time of the day ought to be chosen for the fire-tracing operations. But this point will be dealt with in its proper place lower down.

The width of the guide lines in any case will of course vary with the height, density and inflammability of the grass on the trace, with the force and direction of the prevailing winds, and with the readiness with which the area adjoining can take fire and burn. Thus local knowledge and experience can alone determine in any given case the minimum safe width to adopt. But subject to not very important modifications imposed by local conditions, the following empirical rule may be laid down:—*The width of guide lines should be more or less equal to the height of the grass through which they are cut, increased by 3 feet.*

Whether the rest of the trace be cleared or not of trees and shrubs, no such vegetation should be allowed to stand on the guide lines, for the burners must have free room for unimpeded circulation and for wielding the leafy branches with which they beat out the fire and prevent it from spreading beyond the trace. The trees and shrubs may be got rid of entirely by grubbing out, if the operation is inexpensive and money for it is available; otherwise they must be felled once for all and the resulting coppice shoots cut every year.

If there are no thick stems in the way and the ground is sufficiently level and not stony, a scythe will be the most expeditious implement to employ in clearing the guide lines of its grass and other vegetation. Otherwise a sickle must be used. According to the width to be cleared, men may be placed singly or two or three abreast at convenient distances apart.

The grass cut off the guide lines should be thrown up in a continuous mass along the edge of the standing grass on the traces. There it dries and becomes inflammable rapidly and thus facilitates the firing of the trace: without such a cushion of dry grass it would be extremely difficult to fire the standing grass on the trace,

and in the most favourable circumstances this grass would never take fire and burn regularly. Even when the standing grass is too green to burn, the combustion of the cushion of dry grass causes the green grass in contact with itself to be consumed and thus widens very materially the guide line and renders the second attempt of firing the trace a safe and easy matter. If the grass on the guide lines can be sold, advantage should be taken of this circumstance to reduce the cost of fire-prevention, and the best plan then would be, if that were feasible, to get the purchaser to clear the lines. The unsaleable portions should of course be thrown up against the edge of the standing grass as described above; and if there is not enough to form the requisite cushion and at the same time supply material for the fire-brands (p. 455), a slight additional width should be cleared on the inside to obtain the balance.

The guide lines should be cleared while the standing grass is still green and a sufficient time in advance of the firing to allow the cut grass to become completely dry and inflammable by then (for season for firing see below.)

To ensure permanence for a fire-trace, as well as for economy's sake to follow as straight a line as possible everywhere, it is advisable, whenever practicable, to mark out the edge or edges of the trace by means of a trench. When such a trench has been made, it may, if it is wide enough, render unnecessary the clearing of a regular guide line, all that might be required being either to beat down the grass along the inside edge or to cut it over in a narrow strip just sufficient to form a dry easily inflammable cushion and supply fire-brand material. The trench will of course require to be kept up, but the cost of its maintenance added to its initial cost with interest, will, if due judgment has been exercised, never equal the outlay on clearing regular guide lines every year.

2.—Should fire traces be cleared of trees and shrubs?

In favour of keeping fire-traces free of woody vegetation it must be admitted that the grass and other herbaceous growth on them would, owing to frost or drought or earlier seeding, &c., die and dry up everywhere sooner and more uniformly than in the adjoining forest-covered area, and that their firing would consequently be facilitated and the risks attending that operation minimised, if not entirely removed. Moreover on a completely cleared trace the grass would obviously come up more or less abundantly everywhere and hence burn equally all over the line, instead of remaining uncon-

sumed in patches in the vicinity of bushes when a steady breeze has been wanting during the firing. In the event of such patches being left, the least that could happen would be that a second and even a third and perhaps fourth firing might be required; and if there was bad luck, a conflagration might in the meanwhile cross the trace in consequence of those patches maintaining a connection between the areas it separates.

If the arguments in favour of clearing fire-traces of all woody growth are great and unquestionable, on the other hand two very important considerations may, and often do, militate against its being carried out: *firstly*, the great cost of such an operation, since all stools, woody rhizomes and sucker-producing roots have to be grubbed out or otherwise the annual coppice must be cut down with infinite labour during the growing season; and *secondly*, the immense sacrifice of forest growth involved, if the traces are at all broad and thus aggregate a large area. Moreover such open lines might give ingress to dangerous winds. But when there is a cleared line of sufficient width defining the boundary of the forest, the necessary trace exists there ready to hand, and the charge for clearing it is of course not one that is debitable to fire-conservancy.

In discussing the question which heads this sub-article it is a mistake to suppose, as has often been done, that cleared traces escape being covered over with a deposit of dead leaves and that they thus save the trouble and expense of sweeping away this highly inflammable stuff during the season that trees shed their old foliage. Leaves falling from the trees bordering a fire-trace are always wafted on to it in sufficient abundance to make it dangerous.

3.—Season for firing the traces and the number of times to fire them.

A trace can be completely cleared in a single firing only under one of two conditions; either the grass on it should everywhere be dry, or, if it is not all quite dry, a steady breeze should be blowing during the firing operation to cause the combustion of the still moist portions. Now we know that the simultaneous drying up of the grass on any considerable length of trace is a rare, if not an impossible, occurrence, while such a wind as is necessary to assure the combustion of grass that is not uniformly dry and is yet not too strong for the safe conduct of the firing, cannot be expected to blow whenever and wherever it is wanted. To wait until all the grass on the fire-traces became combustible would mean the daily and even momentary risk of an outside conflagration entering the forest by

way of the portions already dry. Indeed such waiting would mean even more than this, for by the time the grass on the traces had everywhere become dry enough to burn, that on the preserved area would also have become inflammable, so that there would always be the danger, if the fire on the burning trace got out of control, of its spreading away unchecked into the forest. Hence a safe rule to follow in practice is to commence firing a trace as soon as there is enough dry grass on it to enable it to burn in a more or less continuous manner ; whatever grass remains unburnt must be got rid of by a second, and, if found necessary, also a third and even a fourth firing. These subsequent firings need not cause any alarm on the score of expense, for they must in any case be undertaken in order to clear the traces of dead fallen leaves.

It is obvious that different considerations determine the time for firing boundary and internal traces, for the former must be made sufficiently effective for the time being before there is any danger at all of fire entering from outside, while the latter need not be ready until the grass inside the forest has become so dry as to make it a difficult, or at least an uncertain, matter to attack directly and beat out any conflagration that might occur.

Taking up first the case of boundary traces, we note that in preparing them one of the three following distinct sets of conditions has to be dealt with :—

(1) *The trace may be flanked by a road or a watercourse, which thus itself constitutes a part of the width of the trace.* Now we know that during the early part of the fire-conservancy season, conflagrations can neither spread rapidly nor are so violent as not to be stopped by a comparatively slight obstacle. Hence there is no need for any hurry, and, unless strong constant winds blow towards the forest, the trace need not be fired until most or all of the grass on it has become inflammable.

(2) *The grass on the entire or partial width of the trace may dry up appreciably earlier than in the forest.* This may be due to the trace being on a well-drained ridge, or to the fact that the boundary of the forest is demarcated by a cleared line exposed to all weather extremes while the area to be preserved is covered with more or less canopied forest. Here also there is no need for hurry and the firing may be delayed until all or most of the grass on the trace, or at least on the portion of it devoid of tree-growth, is fit to burn. We have a special and the simplest instance of the present case when the area outside the forest is not to be protected against fire and the grass on it dries up early.

(3) *The grass on the trace may become inflammable before that immediately inside the forest.* This is a real difficulty to overcome, especially if the grass on the trace, from being in moister soil, remains green longer than in the adjoining protected belt. If there is no cleared line to mark the boundary of the forest, one should be made without delay, so as to bring about, if possible, the earlier drying up of the grass on the trace. But if that measure should prove ineffectual or insufficient, one or both of two further expedients still remain to be adopted. In the first place, the green standing grass on the cleared portion of the trace may be beaten and crushed down with poles or light wooden rollers (according to the broken or even nature of the ground), so that it dries early and burns more easily and completely in its now recumbent position. If this operation is found too costly and can be dispensed with, then the following simple device carried out with care and intelligence should answer in every case. Starting originally with somewhat wider guide lines than would suffice under the other circumstances of the case, the cushion of cut grass should be well and evenly laid, the standing grass along the edge being beaten down, if necessary, to facilitate the operation. The result of firing this cushion will be to increase very appreciably the width of the guide line, and if the firing is delayed as long as possible consistently with the safety of the forest, in most places a certain belt of the standing grass will also be consumed. The guide lines thus widened ought to present a sufficient obstacle to the passage of fire until the remainder of the grass on the trace, or at least most of it, is dry enough to be fired. If there is danger in waiting until the whole of the grass is dry, the second firing should be undertaken before such danger arises, and the trace must be finally cleared by a third firing. Occasionally a fourth firing may be found necessary.

We now come to the consideration of the time for firing internal lines. It has been said above that they need not be ready until the grass in the forest is so dry as to render the direct attack and extinction of a conflagration a difficult or at least an uncertain matter. But, on the other hand, it is evident that the earlier they can be cleared, in order to minimise the risk to the forest in the event of the fire on the trace getting out of control and crossing the guide line, so much the better. Hence if the grass on the trace dries before that on either side of it, it should be burnt without delay, or at any rate before the latter becomes inflammable. But

it is seldom that the grass on an internal trace is fit to burn thus early, for such traces generally flank either a watercourse or a road cut through as heavy forest growth as the average of the area to be protected. Nevertheless the fact of such road or watercourse forming one side of the trace diminishes very considerably the risk of late firing and in most cases enables the forester to wait until the grass on the trace is nearly all dry. Here we see proved the great importance of clearing the trace on the windward side of the watercourse or road, which at first, until the grass in the forest is nearly dry, serves as an internal fire-break itself, and later on, when the trace is fired, acts, if wide enough, as the very best possible guide-line. If the width of the road or watercourse is insufficient for this latter purpose, a few feet of the standing grass will of course be cleared along it early in the season, formed into the usual cushion and burnt as soon as it is dry. This, really the first, burning will obviously extend in many places beyond the cushion of cut grass, and at some points even over the entire width of the trace, and thus render the subsequent or main firing operation an easy matter. If at certain points the bed of the watercourse is overgrown with grass, this grass will also be cut early in the season, spread out evenly and fired as soon as it is inflammble.

Only one more case of internal traces, *viz.* that in which the grass is to be cleared on both sides of a much frequented road, remains to be considered. The firing of the grass on the windward side of the road falls under one of the cases discussed in the preceding paragraph, so that we are concerned here only with the part of the trace to leeward of the road. It is evident that the firing of this part of the trace must offer no little difficulty if the grass on it does not dry before the adjoining protected grass. The only way to overcome this difficulty is to clear early in the season a wide guide line, form the cushion of cut grass carefully, beating down if necessary the standing grass on which it is to be laid, and firing this cushion before, if possible *just* before, the grass in the forest becomes inflammable. By this means the guide line will be sufficiently widened to prevent any risk at the second firing, which should be undertaken as soon as most of the remaining grass is in a condition to burn. It will generally be found possible and advantageous to effect the first firing of the trace on the windward side of the road simultaneously with this second firing of the lee side, thus combining the two operations into one and economising both time and money.

From what precedes it will have been observed how essential to the success of fire conservancy the proper choice of the time for firing the various traces in a forest is and on how many changeful

circumstances, that require to be carefully and intelligently noted, that choice depends. How often do we not read in the Annual Progress Reports of our Forest Department of large conflagrations due solely to fire having got of control and spread away into the forest from a trace that was being cleared! Most of these conflagrations might have been avoided had the traces been fired at the right time. It is evident that the less experienced and steady, and the less inured to face a high-blazing mass of grass the fire-tracers are, the greater is the necessity for care and judgment in choosing the right time for firing.

4. *Time of day for firing.*

The time of day during which to fire-trace will depend on the season of the year, the nature of the Cold and Hot weather in the locality, and the absolute and relative condition of the grass in the forest and on the trace.

We must fire during the day time in the following several circumstances :—

(*a*) If dews are heavy and the grass is too wet to burn between sundown and an hour or more after sunrise. If the grass in the forest is not very inflammable and the wind permits of it, the firing may be commenced from the time the dew has disappeared and continued as long as the grass is dry enough to burn. But if the grass in the forest is in a dangerous condition, it is safe not to begin firing until past noon, so that nightfall with its heavy dews and low temperature may not be far off in case the fire from the trace got into the forest.

(*b*) If the grass on the trace is dry, whilst inside the forest it is not yet inflammable.

(*c*) If the grass everywhere takes fire with difficulty.

(*d*) If the grass is everywhere green and it is essential to increase the width of a check line or the effectiveness of roads or watercourses by burning a cushion of cut grass as explained above (pp. 449, 452 and 454).

(*e*) When no guide lines are cleared, for at night it would be impossible to follow the line to be burnt. For safety's sake, unless the grass everywhere, or at least in the forest, was green, the firing should generally commence in the afternoon.

We must fire only at night in the following cases:—

(*a*) When the grass has everywhere become more or less readily inflammable, especially in steep hilly country with sharp crests and ridges.

(*b*) When, there being no dew, high winds render work during the day dangerous.

(*c*) In the height of the hot weather, when it is impossible for any one to face a grass fire during any other period of the twenty four hours.

In every other case the work of firing should begin late in the afternoon or an hour or two before nightfall, according to the nature of the season and the condition of the grass in the forest; and it should be continued as late into the night as the men can hold out or the dew, should dews still prevail, will allow the grass to burn. It is evident that in the most favourable circumstances the appearance of dawn should be a signal for closing work forthwith.

5.—*Firing the traces.*

The simplest and most expeditious way to set fire to a trace is to take up loosely a bundle of dry grass, holding it by the upper and smaller end, and when it has been fully lighted at the lower end, to trail it along over the grass to be burnt, the wrist being twisted about in opposite directions. This motion of the wrist is necessary not only to keep the bundle of grass in constant active combustion, but also to drop at short intervals in the midst of the grass to be consumed blazing fragments of the burning bundle, without which a continuous line of fire could not be established and the trace thereby rapidly and easily cleared. We will, for the sake of convenience, call the burning bundle of grass a *fire-brand.*

In firing a trace for the first time, at whatever other point also the grass may have to be lit, a fire-brand must always be run along the cushion of dry grass formed on the edge of the grass to be burnt. When a sufficient length of this cushion has been ignited, the fire must of course be allowed to spread away into the trace, but should be put out on the outside before it can get across the check line into the area to be protected. It should be beaten out with thick bunches of leaves or stout leafy twigs, which bunches may aptly for shortness be termed *brooms.* The best brooms are made by tying together 5-10 leaves of any date palm; these are often still serviceable after a long day's work. Failing date palms, the smaller branches of any broad-leaved forest tree with numerous agglomerated tough leaves possessing strong petioles may be used; the leaves should be fully mature, and if they are caducous, their shedding time should be still remote, otherwise they will shrivel up or disarticulate off after very little use. Such brooms do not, however,

in the most favourable circumstances, last long and have to be renewed several times during a single firing operation, thus necessitating the detailing of several men exclusively for the cutting and constant supply of the requisite quantity of broom material.

A few brief remarks are necessary regarding the use of the fire-tracer's broom. As a rule, no attempt should be made to beat out the fire until it has begun to creep outwards away from the cushion of dry grass, most of which has by such time been consumed or has at least ceased to flare up. To attack it earlier would mean totally unnecessary exposure of the broom-men to fatigue, discomfort and even suffering, without in any way accelerating the work, for the fire would be burning too fiercely in the cushion of dry grass for much impression to be made on it by the efforts of the men. In beating out the advancing fire, the broom should be brought down with a sort of oblique sweeping motion directed towards the trace, thereby not only smothering up the fire, but also brushing away on to the trace burning fragments that must otherwise only cause it to flare up anew before the broom could be brought down again. If the broom were brought down vertically, these burning fragments would be scattered about in every direction and some might fall amongst and set on fire the standing grass or accumulation of dead leaves just outside the trace. The force with which the broom should be brought down will obviously depend on the violence of the advancing fire, and the more violent it is, the closer together must the broom-men be ranged along the edge of the trace. The fire in the cushion of dry grass may be so fierce that the men, while waiting to attack it, may be obliged to stand in the midst of the grass and bushes beyond the guide line. To protect themselves then, and also when they advance and attack the fire, they should screen themselves behind a bunch of leaves or twigs held in the left hand. Without such protection the men would be exposed to extreme discomfort, and would often be unable to approach the fire near enough to beat it out. Indeed they should *never* be without such fire-screens. In beating out a violent fire care must be taken that when the broom is lifted back to strike again, fragments of burning grass or leaves are not thrown backwards from it into the protected area, a by no means unusual occurrence.

If, while a trace is being fired, a dangerous wind should spring up,

the work should be stopped at once. It is false economy to go on with the operation on the plea that the men being all out on the spot, their services must on that account be utilised. Should the fire spread into the forest, as it is bound to do in nine cases out of ten, the diminished area actually protected would mean an appreciable increase in the cost of protection per acre. If the grass in the forest is very dry, the first occurrence of any symptom of a whirlwind should be the signal for stopping work at once.

In fire-tracing the effect of a large mass of fire to produce a strong draught of colder air towards itself should never be forgotten and should be made the most of. A few remarks on this subject will not be out of place. The air being still, if a single line of fire were burning, the flames would all ascend vertically, the draught from opposite sides being equal; but if a second line of fire parallel to, and not far from, the first were now lit, each line of flames, instead of rising up straight, would be inclined towards the other under the influence of the markedly preponderating draught from the off side, the space between the two lines being obviously too narrow for the production of any appreciable draught towards either fire. Next let us suppose that a wind was blowing while the single line was burning; the flames would in that case be obviously bent by the wind in the direction in which it was moving, the deflection from the vertical being proportionate to its velocity. If the second line of fire were now lit to windward of the first, the current of air constituting the wind would, on reaching this new line, be more or less forced upwards, partly owing to a rise of temperature, partly and more especially in consequence of encountering the broad ascending column of air over the two fires. So much of it as could traverse the new line of fire and reach the first across the narrow interval separating the two lines would have too high a temperature to receive much acceleration from the combustion of this further line, and even this acceleration would, as the two fires approached each other, diminish to such an extent that the opposing draught of air coming in from the other side would ultimately be strong enough to bend the flames in its own direction. We thus see that by a very simple and inexpensive device the long flames, which rise when the cushion of dry grass along the edge of a trace is set on fire, can be turned away from the broom-men, even if a contrary wind is blowing. From the above considerations we derive the following practical rules. If the air is still, an inner parallel line of fire may be lit a few yards away from

each edge of the fire-trace. A single line along the middle of the trace will, however, suffice if the width of grass to be burnt does not exceed say 40 feet, and none at all will be necessary if it should be less than half that figure. If a wind is blowing across the trace, an inner line of fire should be run in order to fire the cushion of dry grass on the lee side with safety or comfort; no such line will of course be required for the other edge of the trace. Lastly, it must not be forgotten that if during more or less still weather a line of fire is drawn round any area of small extent, converging currents of air will be produced which will bend all the flames inwards and hasten the complete burning of the enclosed area.

During the firing of a trace one or two men should always follow the firing party at a short distance behind, in order to put out or brush or throw away still smouldering fire that is in dangerous proximity to the preserved grass on either side. Often large dry fallen wood, and even portions of standing trees take fire; if allowed to burn on, they would prove a serious menace to the safety of the forest, should a strong wind spring up or a tree or a large branch be burnt through and fall across the trace. The burning portions should be at once completely cut out. The men should be armed each with a broom, a sickle, a light axe and a pitch-fork, and they should be expert at climbing trees. They should leave behind them nothing that is dangerous and ought to be put out.

Fire-tracing is very dry and exhausting work and the men must have a constant supply of good drinking water with them. One or more men should be told off specially to bring this supply from the nearest source. In some districts pools of good drinking water are met with at numerous points along the traces during the cold weather, when the main part of the fire-tracing work must be accomplished; there the men could wait for a drink until the nearest pool was reached. In very dry localities wells must be sunk at certain intervals; but we shall have to say more about this lower down.

It remains to advise the student regarding the actual firing of the traces. We will begin by describing in detail the procedure to follow in the first firing of a trace on more or less level ground with a specially prepared guide line on either side. The student will then be able to understand without difficulty the brief remarks that will follow (1) on the first burning of traces on more or less level ground, wherein the fire has to be controlled on one side only, (2) on the first burning of traces on

steep or hilly ground, and (3) on the second and subsequent burnings of traces that have not been completely cleared by the first firing.

I. FIRST BURNING OF LEVEL TRACES ON WHICH THE FIRE IS TO BE CONTROLLED ON BOTH SIDES.—The distribution of the men and the mode of firing will depend on the direction of the wind relative to the trace. The wind may blow either (*a*) in the direction itself of the trace, or (*b*) obliquely to it or (*c*) more or less at right angles to it or (*d*) there may be no wind at all. It is evident that the first case will be of rarest, the second of most frequent, occurrence.

(*a*) *Direction of wind and trace coincident.*—It is evident that the work should march against the wind, otherwise the fire would run along with the wind in the direction of the unburnt portion of the trace and would thus be very difficult, if not impossible, to control. The men should be distributed equally on both sides of the trace. Unless the trace is narrow or the grass short, an intermediate line of fire should be lit on each side to accelerate and facilitate the burning of the cushion of dry grass on that side. If the trace is narrow, no intermediate line of any kind will be required or a single line of fire run along the middle will suffice. A single fire-brand man is enough for each line of fire. The day's work should begin where the previous day's work closed or on the edge of a cross road or watercourse, along which, in commencing work, the fire-brand should be trailed before it is run on to the cushion of dry grass on either side. When a sufficient length of this cushion (the same length on both sides) has been ignited, the men trailing the brands should move off at right angles and meet in the middle of the trace. The cross-line of fire thus lit will sweep back rapidly before the wind, amalgamating in its progress with the fire advancing inwards from the sides of the trace. Another length of the trace will next be fired in the same manner, and then a third, and so on. In this way the trace will be burnt in successive sections of more or less rectangular shape. According to the strength and changeability of the wind and to the height to which the burning grass and leaves flare up, each successive section may be fired either before or only after the preceding one has been completely burnt.

(*b*) *Wind blowing obliquely across trace (Fig. 126, diagram to right).*—More men should be ranged along C D than along A B in

proportion to the inflammability of the grass on the trace and to the strength of the wind and the approach to a right angle its direction makes with the line of the trace. The firing should here also be carried on counter to the wind, *i. e.* from A C towards B D. The party along A B should each time advance their line of fire only when the grass along C D has burnt far away enough from the edge to remove any risk of the fire, as it sweeps onwards from A B, reaching across the burnt portion and setting ablaze the grass beyond C D. The position of the party on A B with reference to that on C D will thus depend on the force and direction of the wind and on the inflammability of the grass on the trace, that is to say, on the rapidity with which the fire lit along A B rushes across the trace. Hence it will often be permissible for the party on A B to keep ahead of the men working along C D, when the wind is not changeable and the condition of the grass prevents the fire from travelling very quickly. No inner line of fire is required on the windward side (A B) of the trace, but one can seldom be dispensed with on the lee side. Each time a new length of grass is lit along CD, the fire-brand should be run back obliquely inside the trace to meet the inner parallel line of fire and even beyond it, thus closing the quadrilateral *a*CD*a* and drawing the flames away from the broom-men. Owing to the greater difficulty of beating out fire to lee of the wind, the grass along C D should, as a rule, be fired in shorter lengths at a time than the grass along A B, which may, under favourable conditions, be fired in lengths of 30 yards and more at a time by a party of no more than four or five men.

(*c*) *Direction of wind more or less perpendicular to trace (Fig. 126, diagram to left).*—The strength of the firing parties will be still more unequal here than in the preceding case, one fire-brand man and from two to four broom-men being sufficient for the windward side of the trace. With the exception that this latter party should always keep well behind their comrades on the other side and that shorter lengths must be fired at a time on both sides, the work should be conducted in the same manner as in the preceding case. The distance which the smaller party should keep behind the other will vary with the force of the wind, with the rapidity with which fire travels through the standing grass, with the height to which the flames rise, and with the quantity of inflammable leaves strewing the ground or still remaining on the bushes. Such leaves are of course carried up in a burning state and may then be wafted away

and dropped in the same condition amongst the grass beyond the check line. A safe rule to observe is to light up a new length of grass along A B only when the immediately opposite line of fire has been beaten out along the check line on C D and the inner and outer lines of fire lit along that side have met.

(*d*) *The air quite still.*—The procedure to follow is the same as that described under (A), except that if the trace is broad, one or more intermediate lines of fire may have to be lit between the pair of lines along each side of the trace with the object of creating strong lateral draughts to accelerate the burning.

II. FIRST FIRING OF LEVEL TRACES ON WHICH FIRE IS TO BE CONTROLLED ON ONE SIDE ONLY.—The fire may have to be controlled on one side only either because the area on the other side is not to be protected or because the trace on this latter side is flanked by a broad clear road or watercourse or a belt of leafy bushes which the fire cannot cross. The first of these two cases has been already referred to at pp. 447-8. There is little to add to what has been said there. Every effort should be made to keep the fire along the guide line constantly in advance of the rest of the burning grass, and so long as this is secured, fire-tracing offers no greater difficulty here than when the fire has to be controlled on both sides. Hence the rule of burning against the wind is of even still greater importance here than when the fire has to be put out on both sides of the trace. Hence also the necessity of *always* drawing the fire-brand obliquely backwards into the trace each time a new length of the cushion of dry grass is fired. An inner parallel line of fire can never be dispensed with except when the wind drives the flames away from the broom-men, in which case indeed such a line would be worse than a superfluity as it would cause the fire to spread away too rapidly. The distance of this inner line of fire from the cushion of dry grass will depend on the force and direction of the wind, being shortest in still weather and greatest when the wind blows perpendicularly across the trace.* The day's work should not be closed until a cross road or watercourse or some other equally effective barrier to fire has been reached, otherwise the fire that has spread away from the trace may be subsequently turned back and find its way into the preserved forest across the

* We have purposely omitted all reference to the case in which the place of a specially cleared guide line is taken by a road or watercourse, for it is obvious to any one that hardly anything is required beyond running a fire-brand along the edge from which the grass is to be burnt.

still uncleared portion of the trace. All the preceding remarks apply also when a road or watercourse or impenetrable belt of bushes flanks one side of the trace, but with this addition that a line of fire (not of course requiring any broom-men to beat it out) must be run along that side and advance at the same rate as if the fire had to be specially put out on that side also.

III. FIRST BURNING OF TRACES ON STEEP OR HILLY GROUND.—In hilly country a trace may run (*a*) along the crest of a main ridge, or (*b*) along the crest of a spur, or (*c*) along the bottom of a long gulley or ravine, or (*d*) more or less along the line of steepest descent on a flat hill-side or (*e*) more or less along horizontal contours. Before proceeding to consider each of these five cases separately, a remark of common application to them all must be made, *viz.* that everything likely to roll down in full combustion on to preserved slopes below, such as cones, dry billets of wood, &c., should be removed before the trace is fired. It should also be remembered that fire will progress upwards even *against* the wind, and the rapidity of its progress upwards may be alarmingly great even in a still atmosphere, if only the grass and vegetable débris strewing the ground be abundant enough and readily inflammable.

(*a*) *Trace following the crest of a main ridge.*—Where the crest is broad and flat and more or less horizontal, the work of firing it will not differ in any essential particular from the procedure to be followed on level ground. But where the crest is narrowed into a more or less sharp edge forming the middle line of the trace, only a single inner line of fire along this sharp edge should be lit, whichever way the wind may blow, and even if the air be quite still. If the slopes on only one side of the ridge are to be protected, no line will be lit along the crest, should a very violent cross wind be blowing from the other side.

(*b*) *Trace following the crest of a spur.*—This case differs from the preceding only in that the trace would here run for the whole of its length on generally steep gradients, and should for this reason be fired from the top downwards. Otherwise the procedure is the same.

(*c*) *Trace running along the bottom of a long gulley or ravine.*—Here, as a rule, one side of the trace will be flanked by a watercourse. The firing should begin at the highest point. No inner line of fire is required. As soon as the fire from the guide line has burnt down far enough, the grass on the edge of the watercourse should be fired. If there is no watercourse, its place along

the drainage line should be taken by the second guide line, which will now be required.

(d) *Trace running up a more or less flat hillside.*—On easy slopes the procedure will be the same as that on level ground, except that the firing must begin at the highest point. But the ground may become too steep to permit of any inner parallel line of fire being lit, in which case a zigzag path should be made cutting across the trace from side to side, and in order to help the broom-men on the lee side of the trace, an inner line of fire should be run along that side of the path. Where the ground is very rough or steep, the path will often help the men to reach the more inaccessible portions of the guide line. In case the fire is to be allowed to spread away on one side, this path should obviously lie to windward of the guide line, if the wind blows *towards* the area to be preserved; and it will itself become the single guide line required, if the wind blows *away from* that area. The extent to which the path should zigzag will of course depend on the steepness and roughness of the hillside.

(e) *Trace running more or less horizontally.*—Such a trace, if it is not meant to flank a much frequented road, will always be a boundary one. Here, as in the plains, the firing should progress against the wind, the risk of disaster in case the fire got out of hand, especially if this happened on the lower side of the trace, being very much greater than on level ground. If a road or path does not already exist along one edge of the trace, a narrow path, constituting a permanent check line, should be made. When the fire is to be controlled on only one side, all that has to be done is to run a line of fire along the road or path, a new length of it being lit only when the preceding one has burnt far away enough for there to be no danger of its setting ablaze the grass on the other side. If the road or path is broad and the forest to be protected lies above it, then the grass along its lower edge should be lit as rapidly as possible and two and even more fire-brand men may be employed for the purpose. When the slopes both above and below the trace are to be protected, a second guide line must be prepared, and the fire along the upper of the two lines should always be kept well in advance of the other. Obviously no intermediate line of fire will be required. The second guide line may also be of a permanent character in the shape of a narrow path, or it may be prepared by simply clearing away the grass and the fallen leaves, twigs, &c.

strewing the ground; local conditions will determine of which kind it should be. As a rule, the party along the upper guide line should be the stronger of the two.

IV. SECOND AND SUBSEQUENT BURNINGS.—The first firing has often to be undertaken when the grass on long sections of a trace is still green and does not hence burn except along the edges where the cushion of dry cut grass has been formed. More frequently the green grass stands in more or less large patches, especially in the midst of bushy growth. It is evident that all incompletely cleared traces should be rendered effective as early as possible by means of a second burning. The urgency of this operation will be in proportion to the length of the unburnt section, to the size, number and contiguity of the patches (a few of them standing sufficiently near to each other might form an easy line for fire communication between the grass on either side of the trace), and to the inflammability of the grass both inside and outside the trace. It will also depend on the quantity of dry leaves shed by the trees. These dry leaves are at first quite sufficient to connect the patches of standing grass with each other and with the grass outside the trace, and later in the season become abundant enough to litter thickly even the most completely cleared portions of the trace. Long unburnt sections of a trace should be cleared in the same manner as if they were being fired for the first time, the precaution being taken of previously sweeping all fallen leaves off the guide lines towards the edge of the grass to be burnt. This second firing will, as shown before (p. 449), be less troublesome and risky than the first operation, since to the original width of the guide line is now added the cleared belt formerly occupied by the cushion of dry grass and also by some of the standing grass beyond. The burning of the patches is very much easier and seldom requires more than a single man to fire them one by one. This man will find more occupation for his broom in sweeping the dry fallen leaves together round the patches than in beating out fire. The second burning may not suffice to clear the traces completely, as many patches of grass, on traces running through low-lying land, may be still too green to take fire. A third burning will then be required. Indeed, in moist localities the grass may never become dry enough to burn, or may become inflammable so late in the season as to require a fourth and even a fifth burning before it is completely cleared. The forester

need not to be alarmed at the idea of so many repeated operations, for even if all the grass has been burnt off in the first one, the millions of dead leaves shed by the trees and numerous enough, if left undisturbed, to form a layer from six to eighteen inches thick, must in any circumstances be got rid of by fire. As often as they accumulate to any dangerous extent, they should be swept towards the middle of the trace in small heaps and fired. When the leaves are falling thickly, the same trace may have to be gone over at least once a week.

IMMEDIATE SUPPRESSION OF FIRE ACCIDENTALLY LEAVING THE TRACE.—In spite of every precaution and conscientious care the fire will occasionally get across the check lines, whether it be from the wind becoming suddenly very strong or gusty, or because the firing has been delayed at that particular point until the grass has become too dry or the weather too hot for the broom-men to face the fierce conflagration along the cushion of cut grass. The moment the fire has escaped beyond the guide line it should be vigorously attacked at once at its two extremities (Fig. 127, *e e*), the broom-men ultimately, at the moment of putting it out, meeting at (*h*), where it has been making headway. It is no use attempting to overcome it in any other manner, for labour spent in putting it out at any other point but its two extremities will be labour lost, as the fire will only blaze up again almost as fast as it is beaten out. If found necessary, the fire along the guide lines should be extinguished and the whole strength of the two parties concentrated on the spreading conflagration. The fire should be attacked without any intermission, so as not to allow it flare to up again where it has once been beaten out; the party at each extremity should accordingly divide itself into two sections, one resting while the other is working with all its might. The plan here indicated will seldom, if ever, fail, and where it fails, no other will succeed.

STRENGTH OF THE FIRING PARTIES.—The number of men to employ in the first firing of a trace will depend principally on the force, direction and changeability of the wind, on the height, denseness and dryness of the grass both inside and outside the trace, on the quantity of fallen leaves littering the ground, on the experience, endurance and courage of the men, on the temperature and dryness of the weather, on the steepness and broken nature of the ground, and on whether the fire has to be put out on only one or on both sides of the trace. On level ground, when the fire is to be

controlled on one side only, from 6 to 10 men will generally suffice; if the fire has to be put out on both sides, from 4 to 10 additional men will be required. On pronounced slopes a few more men must be employed than would suffice in otherwise similar circumstances on level ground. From what precedes it is evident that, as a precaution against possible accidents, the firing parties may sometimes have to be stronger than the necessities of mere fire-tracing may require.

For the second and subsequent burnings the employment of any but members of the patrolling establishment (see next Sub-article) should be avoided as much as possible. At the beginning the patrolling work is light and comparatively unimportant and the nearest patrols can always be brought together to complete the clearing of the traces. When necessary, a few extra hands can be added for the day.

IV.—Fire Police.

Besides establishing an effective system of fire-breaks, the traces have to be kept clear, trespass, especially on the part of shikaris, has to be prevented, incendiarism has to be watched against, and conflagrations must be at once noticed and put out or circumscribed by counterfiring. All this can be done only by establishing a system of watch-stations, the men posted at which must also patrol along the fire-traces, particularly the more frequented roads and boundaries marching with populous villages. The number of patrols will of course depend on the extent to which the forest is frequented by squatters, woodmen and wayfarers. It has been found by experience that the minimum length that can be efficiently patrolled by a single man under the most difficult circumstances is about one mile. The maximum may be ten or more miles distributed over several inter-communicating traces. Some lines may have to be patrolled daily once or oftener, others it will suffice to visit only once a week or so. But whatever the disposition of the men and the length of their beats, the distribution of the watch-stations at which they live should be such that each man meets both his right and left hand neighbours at least once in the twenty four hours, and receives from one and passes on to the other the news of the day relating to everything connected with the fire-conservancy of the forest. This news thus reaches the very same day the man in charge of the whole work, and, if necessary, also the highest resident supervising officer. Besides details communicated verbally (for it is out of the question to

expect patrols to be able to read and write), a ticket may be given by each man impressed with his distinctive number and denoting, by means of a difference of colour, whether all is well in his beat or a fire has occurred. The man in charge of the fire-conservancy will thus receive every day a ticket from every patrol. If so much elaboration is found unnecessary, there need be no distinctive numbers and one and the same ticket may be passed on from the first to the last man to prove that the chain of communication has been kept up. The verbal details communicated will comprise such facts as the following—whether a portion of a trace is to be re-fired on that or the following day and at what time, what portions require re-firing, how many men are wanted for the purpose, whether a portion re-fired has been completely cleared, or not and so on. And in the same manner orders can be passed back from the head man in charge. In this way every man will have full intelligence of what is going on in the forest and the distant glare of a burning trace will not, as is often the case, be mistaken for a conflagration and uselessly bring out to it troops of men from far and near.

The watch-stations at which the patrols are located should occupy commanding vantage points and be always built up in the tops of trees, where the men will feel themselves secure against ferocious animals and from whence they will be able to survey the forest for a great distance round. The life of a fire patrol is solitary enough and devoid of the smallest amenities which make life endurable ; they should therefore be located by twos at the common point whence their beats start in opposite directions. In some cases, as when traces and roads cross one another, it will be possible to locate three and even four men at one and the same station.

Where water is scarce or at a prohibitive distance from a station, a well should be sunk, if the water-bearing stratum is not too far below the surface. When costly wells have to be sunk, the economy of putting several men together becomes obvious.

In forests where squatter villages exist, the services of the squatters, under the responsibility of the headmen, should be enlisted for patrol work. These services may be secured for some slight privileges entailing no loss of revenue or harm to the forest, or in consideration of a small sum of money or of trifling presents in case of successful fire-conservancy. This system has been adopted with singular success in Berar, where the Author has known an unpaid squatter evince as much concern on a merely glowing match being

dropped in the middle of a perfectly clear foot-path as the forest officer himself might have felt if he saw a flaming one thrown in the midst of dry grass.

One of the most important duties of the patrol establishment is to overcome, either unaided or with the help of other men, conflagrations that it has unfortunately been impossible to prevent. When the grass is short and is not everywhere quite dry and the air is cool enough, the fire may be beaten out with brooms; otherwise counterfires must be lit from the nearest base lines so as to circumscribe the conflagration on every side on which it can spread.

When it is decided to beat out the fire, it should be attacked by one or several parties according to its extent and the length of fire to be put out. Each party, as soon as it has commenced operations, should divide itself into two sections, one moving off to the right, the other to the left, and care must be taken that the fire does not re-kindle at any point where it has once been beaten out. If the conflagration is small enough to be put out by a single party, it should be attacked at the middle point of its windward edge, so that the extinction is completed by the two sections of the party joining hands somewhere near the middle point of its lee edge. To adopt any other plan of attack would oblige the men to face a roaring mass of advancing flames, thereby not only exposing them to extreme discomfort, but also rendering their efforts more or less ineffectual. If the circle of fire is too large for a single party, the several parties employed should be distributed so that each section may be fully utilised and none may have to work against the wind. The distribution of the men must be effected with a full knowledge of the ground and the forest, the most being made of neighbouring roads, paths, watercourses, cliffs, traces, belts of evergreen bushes, fringes of canopied forest, &c. Where an impassable watercourse or road is close by, it is obviously waste of money and energy to try and save the narrow strip of grass that intervenes; and where the fire is likely to spread most, there the main effort should be made; and so on. As in the case of fire escaping from a trace, the brooms should be used without cessation, and half the broom-men should be resting while the other half is working with all its might and main.

Counterfiring requires a still more complete knowledge of the ground, for the absence of this knowledge will not only lead to a wasteful distribution of the men, but may re-

sult in portions of the forest being fired that need not have been sacrificed at all, and even in the causing of a new and more extensive conflagration. If a base line from which to counterfire exists in the shape of a clear road or watercourse or trace, or of a belt of evergreen bushes, &c., the grass along the edge of it should be fired as rapidly as possible, the fire being beaten out with brooms wherever it is likely to burn back across the line into the forest on the other side. When no continuous base line exists, the nearest ones, together with any large patches not covered with grass and leaves that may lie in the way, should be connected by check lines cleared as quickly as possible, and to prevent delay the firing party should follow only at a short distance behind.

Not unfrequently we may combine the two methods of overcoming forest conflagrations, beating out the fire along the wind-struck edge, where the grass does not burn up high, and counterfiring elsewhere.

It will have been observed that in order to overcome a conflagration a great number of men are required, generally many more than the available number of patrols (all the patrols cannot obviously absent themselves from their beats); and for this reason standing arrangements must be made with neighbouring villages, workmen, squatters and graziers to come out to a fire at the first alarm, full remuneration being of course given when necessary. Every one should be armed with a sickle and a light axe, which tools the patrols themselves should constantly carry about with them.

A sufficient supply of water should always accompany the men. In many parts of the country the men would take out most of their own supply with them in gourds. Parched gram may be distributed amongst the men, and if there is any probability of their being kept out a long time, sufficient quantities of flour, salt and dal should be sent out with them.

When a conflagration has been got under, small parties of men should be at once sent round the perimeter of the burnt area to put out all burning trees, branches and other fragments, which are likely to endanger the safety of the surrounding forest.

V.—General.

There is very little more left to say regarding fire-conservancy. The first essential to success is to gain and retain the good will of the people ; without it the most elaborate and costly measures will prove futile, for nothing is easier than to fire a forest without any fear of detection. With the sympathies of the people on the side of the

forest staff, although they may not willingly acquiesce in the restrictions which necessarily follow in the wake of fire-conservancy, cheap, often gratuitous and spontaneous, help will be obtained in fire-tracing and putting out conflagrations and in the prevention and detection of offences. These sympathies may be won by small concessions, made from time to time and in no haggling spirit, which concessions cost the forest proprietor little or nothing and hurt the forest still less. It is essential that the staff in charge of a forest under protection from fire should possess perfect tact and temper.

We must here draw attention to the great importance of compiling a fire-conservancy map for every forest under protection. Such a map should show every fire-trace. When a trace follows a road or watercourse, it should be represented on the proper side of it. Not unfrequently a fire-trace is taken across a road and especially a winding watercourse, in order to save distance or to get into grass that is easier to burn, or to utilise a natural barrier of evergreen bushes, &c. As a permanent record for constant useful reference all such vantage points and lines, as they are discovered, should be noted on the map. On the map should also be marked by distinctive colours or symbols all other barriers, natural or artificial, which require little or no clearing to serve as effective fire-breaks or which, although of no real use as fire-breaks, offer special facilities for counterfiring. The prevailing directions of the wind during the course of the fire season, especially during the most dangerous part of it, should be indicated by means of arrows. The widths of the different fire-traces should be shown by means of figures or in any other convenient manner. All watch-stations should be marked, as well as the various beats. The number of patrols located at the several stations should be indicated either by means of figures or symbolically. The scale of the map should of course be large enough for the convenient representation of all these details, and in order not to crowd too many lines into the map, only the principal topographical features should be shown and hill-shading, if employed, should not be too close. The map should always be posted up to date. With the help of such a map any one would be able to grasp at once the conditions of fire-conservancy in a given forest and the manner in which the work was being carried out. A man coming in charge would not have to grope about in the dark until, after several years of study on the ground and perhaps several disastrous failures, he had mastered all the details of the work. Supervision would become singularly easy, work would be thoroughly and efficiently organi-

sed, mistakes and weak points at once detected and remedied or strengthened, and everything reduced to a system. Improvement could rapidly follow improvement until the fullest advantage was taken of natural aids to minimise risks, and to save labour, time and expenditure.

As a useful record for instructive reference a copy of the fire map for each year should be filed. At the close of the season all areas burnt during its course should be indicated on it by a light wash of Indian ink or some colour.

In conclusion, we cannot impress too strongly on the student the necessity of keeping fire out of every one of our forests, even at what might be considered a high rate of expenditure per square mile. This rate need never, under the most unfavourable circumstances, exceed Rs. 40, which is equivalent to only 1 anna per acre per annum or less than Rs. 7 in a hundred years. This trifling outlay, which is smaller than the cost of an acre of plantation or direct sowings only a few years old, will give a complete new self-sown crop of nearly mature trees, besides whatever produce may have been taken out during the interval as various individuals one after another succumbed in the struggle for existence. And then we must remember that the acre of plantation or direct sowings itself can come to nothing without continued protection from fire.

CHAPTER II.

ATTENTIONS TO GIVE TO THE SOIL.

These attentions have for their object the bringing of a given soil to, and its maintenance at, that condition of physical and nutritional fitness, which will enable the crop actually on it to yield the highest outturn of which it is capable. Direct means to attain and maintain this condition, such as form a necessary part of agriculture, are of course out of the question in forestry except on the most restricted scale. The forester must mainly rely on the employment of indirect means. These consist essentially of protective measures, which are nevertheless, if wisely carried out, quite sufficient not only to preserve the productive capacity of any soil in question, but also to augment it. The productiveness of a soil depends principally on its depth, its compactness, the amount of moisture in it, and its richness.

Depth.

No amount of attention can modify to any great extent the depth of a soil, but existing conditions can of course be almost indefinitely improved and deterioration can be effectually prevented.

In a very shallow soil, whether it is well or poorly stocked, we must studiously refrain from making clear fellings and from otherwise exposing it and thereby causing it to dry up, impairing the formation of humus and hindering the fertilising action of the atmosphere. Regeneration should be effected slowly and under cover, fellings should be light, and all advance growth, and, if necessary, even undershrubs, should be carefully preserved. Especially should this be the procedure on a thin layer of soil resting on boulders, particularly if these be limestone or dolomite. When once this layer of soil has disappeared, the strictest protection is required to restore it; and even then the process is an extremely slow one, since what little soil is formed every year *in loco* by the weathering of stones and rock surfaces is easily washed away by rain. For this reason every scrap of spontaneous vegetation appearing, from the first stage of mere scattered tufts of grass to the last stage of undershrubs and shrubs, should be most carefully preserved. The spontaneous vegetation should be supplemented by scattering seeds

of grasses and hardy gregarious weeds and undershrubs. Ultimately when all this precedent vegetation has rendered the place suitable for tree-growth, this last should be introduced by sowing or planting at points where soil has collected or has been brought together for the purpose.

The protection of unstable soil on slopes and the fixing of drifting sands are subjects that have already been adequately treated, the former at pp. 236-41, the latter at pp. 232-5.

Compactness.

A certain degree of freeness of the soil, sufficient for unimpaired root-aëration and exposure of its interior to fertilising atmospheric action, is a most important factor of productiveness. To prove this we have only to observe the vast difference in development of plants of one and the same species and age grown in thoroughly loosened soil and in one that has been subjected to no kind of cultivation at all.

Soil constantly under a leaf-canopy and covered with dead leaves and low vegetation cannot, like bare exposed land, be hardened by the pelting action of rain or by the sinking of water through it; while the decaying and decayed leaves at the surface and the root fibres and hairs in the interior have a direct effect in loosening it very appreciably throughout its mass.

Very stiff soils should never be exposed and regeneration thereon should hence be effected under cover.

Amount of moisture.

The moisture in a soil is the most important factor of its productiveness. Without sufficient moisture, the richest soil will be sterile, and with a constant supply of it the poorest soil will grow magnificent forests.

We have already at pp. 238-9 shown how energetically the soil on forest-clad slopes holds water in store for the benefit of the vegetation on it. This is still truer of level land under forest. To enable the soil to retain as much moisture as it can contain we require the presence of a constant leaf-canopy, a form of crop suited to local conditions, avoidance of large clearances, and, whenever possible, regeneration under cover and preservation of the entire covering of humus, dead leaves and grass on it. When it is not possible to maintain a complete leaf-canopy, the requisite protection should be afforded by utilising, wherever the leaf-canopy is interrupted, advance growth, stool-shoots and suckers of tree-species,

and where these are absent, also shrubs and undershrubs, and even grasses and herbaceous weeds.

We know that winds accelerate the evaporation of soil moisture in a very marked manner. They should hence be kept out of forests as much as possible, and in exposed places, such as the edges of the forest, sharp ridges and peaks, saddle-backs, the sides of roads, &c., their effects should be diminished by raising fringes several yards wide of evergreen trees or at least of trees that retain their leaves throughout the whole or the greater part of the hot weather. These fringes should be worked either as coppice or by jardinage, or be felled only after obtaining a complete advance growth, supplemented, if necessary, by artificial means. The fringes will also break the wind and throw it up, thus preventing it from entering into the midst of the trees beyond.

Hillsides, as we know, dry up very easily, firstly, because the gradient accelerates drainage, and, secondly, because the wind impinges upon them; and the steeper the slope is, the more immediate is the result. This being the case, on all steep hillsides we should have either jardinage or regeneration in groups, and should carefully preserve all shrubby growth as well as weeds not interfering with reproduction. Where there is no danger of erosion, the soil may be hoed up, the clods checking surface drainage and retaining a very large quantity of water for some time after the last shower of rain has fallen, or the snow has melted, as the case may be. Although the cost of a single hoeing is heavy, yet the effects last for many years, and if the cost is distributed over those several years, the average figure per annum becomes trifling compared with the amount of good secured. But the most effective method of utilising atmospheric precipitation on a dry slope is to excavate short horizontal trenches, each line of trenches breaking bond with the lines immediately above and below it (see p. 264, para. 4 and p. 262, para. 4)

Irrigation and drainage need not be referred to here, as we have already, at pp. 242-3 and 226-31 respectively, said all that need be given in this Manual regarding such work.

Richness.

No direct manuring on any appreciable scale is of course possible in forests; but, on the other hand, some new soil is always formed by the weathering and disintegration of rocks and stones, and the

dead leaves and other vegetable disjecta restore to the soil, in the most highly concentrated and utilisable form, mineral matters absorbed by the trees from the entire thickness of soil penetrated by their roots. Moreover the decomposition of these disjecta, and the loose condition of the soil brought about by their decomposition and that of the innumerable root fibres and hairs in its interior, help it to fix no inconsiderable quantity of carbonic acid and nitrogen from the air.

Nevertheless, as we have seen before, the decomposition of the vegetable disjecta may be so slow that it may produce an acid humus if too much moisture be present, or the undecomposed portion may form so thick a layer as to prevent any natural reproduction from seed taking place. These drawbacks do not often exist, and we have explained in various places what measures to adopt in order to overcome them when they do exist. Briefly speaking, these measures are either the removal of a portion of the undecomposed layer, or mixing it up with the mineral soil below, or driving cattle or pigs over the area, or the free admission of air throughout the decomposing or incompletely decomposed mass by turning it up and opening out the leaf-canopy above, if this be too thick.

General.

From the preceding remarks it will be seen that all the factors which jointly compose the productiveness of a forest soil are increased and maintained by one and the same measures, *viz.* the maintenance of an unbroken leaf-canopy and the preservation and proper decomposition of the decayed and decaying leaves, &c. littering the ground.

CHAPTER III.

REARING OF THE CROP.

After a crop has been created and established various operations are required in order so to regulate its development that during every period of its existence it puts forth the full vigour of which it is capable under the prevailing conditions of soil, climate and species, and fulfils to the utmost extent the object of its existence. At times they come in as a corrective, at others their purpose is to remove hindrances to the prosperous growth of the crop, at others again their effect is to directly foster this growth, and occasionally they may combine any two or all three of these purposes. Some of these operations may be essentially unproductive, yielding no pecuniary return for the money and labour spent on them, while others, although they may be unproductive in the absence of a good market, nevertheless yield produce of less or greater value, which we have already termed *intermediate* major produce as distinguished from that of the regeneration fellings, which we have termed *principal* major produce.

The first condition for the prosperous growth of a crop is of course a suitable soil; but we have already seen how the productiveness of a given soil depends on the kind of crop on it, so that it depends to a great extent on the manner in which the growth of the crop is regulated. Hence in the operations which are now about to be described the care of the soil should never be left out of sight. The double purpose to be thus served by these operations may often make their execution extremely difficult and call for the greatest circumspection and judgment on the part of the forester.

Although these operations influence in no little degree the growth of a crop and increase both the quantity and quality of the yield, still there are unfortunately very few forests in India in which they can be attempted at all, and even amongst these there is only an excessively small proportion in which they can be carried out in a complete manner. The reasons for this are manifold. In the first place, most of our forests are in too ruined and open a condition for work of the kind to be possible there; in the second place,

money can seldom be spared for unproductive operations that are necessarily very costly ; in the third place, there is either no market at all for most of the intermediate produce or its selling price is so low as not even to recoup cost of felling and removal ; in the fourth place, the exercise of rights and especially the wholesale concessions made to grazing interests leave us but few forests in which we can adopt any intensive system of treatment ; and in the last place, our establishments are as yet too small and, in many cases, also too little instructed and experienced, to carry out operations which require close and constant attention and the highest skill.

Such being the case, it might be considered sufficient to describe these various operations in a summary manner. We are, however, of opinion that a Manual which professes to treat of general principles, would be incomplete without a more or less full discussion and exposition of so important a branch of sylviculture. The minuter developments of the theory of thinnings, on which alone a large volume could be written, have obviously not been touched upon.

The young crop requires a different kind of treatment from the older one. Where the one stage of treatment ends and the other begins depends on the constitution of the crop and the purpose it has to fulfil, and on the nature of the soil and the climate.

We may nevertheless, without being guilty of any practical error, say that in the first stage we protect and strengthen the crop and regulate its composition and development during the phase of rapid elongation before the component trees have assumed a tendency to expand themselves laterally with vigour, while in the second we control and foster the growth of the crop when the component trees have begun to show this tendency. The second stage can of course be precipitated if the early production of stems of a certain diameter is specially required, but then *per contra* length of stem and bole has to that extent to be sacrificed.

SECTION I.

Fostering operations in a young crop.

During the early life of a crop we must protect it against causes of injury extraneous to itself, directly foster its growth, and rid it of those elements, which, while undesirable in themselves, not only occupy room that would be more profitably filled by more valuable individuals, but also harm these last. The great utility of advance growth in regeneration operations has been proved over and over

again in Book II; but in order that it may continue to form a useful and desirable element of the crop it requires to be specially looked after. Otherwise it either becomes stunted and bushy and incapable of shooting up when the parent crop has been removed, or, if it has come up in a crowded condition, it forms thin, lanky, small-crowned, hide-bound individuals equally incapable of growing up into tall vigorous trees.

ARTICLE 1.

Protection against extraneous causes of injury.

These causes are frost, excessive insolation, winds, weeds including grass, animals and parasites.

Frost.—Where regeneration is effected under cover, a certain number of the parent or nurse trees must be preserved beyond the period that they would be kept if it were only a question of admitting the seedlings to a sufficient enjoyment of light and other beneficial atmospheric influences. Considered from a purely sylvicultural point of view, these trees should belong to species possessing light foliage; but as it may often happen that there are in the upper crop a number of trees of the more valuable species which are still growing and to which a slight increase of diameter would give a considerably enhanced money-value, the trees to be preserved as nurses are selected on other than mere sylvicultural grounds. Economical have to yield to cultural considerations only in so far as that, if the individuals to be maintained have broad and thick crowns, their number must be limited. Where the coppice system is employed, stores must be kept, even if only firewood is required, and the rotation ought to be long enough to enable the coppice to get up well above the height reached by the severest frost. In all naturally regenerated crops scattered individuals of fast-growing hardy species should be encouraged to push ahead. In stocking complete blanks with a delicate species, a nurse crop of one or more hardy species should be raised in advance, or some hardy, very quick-growing species should be mixed. In the former case, if artificial means continue to be employed, the preliminary species will be worked out and regenerated first, so that the nurse crop will always be ready when the time comes for exploiting the delicate species. Other measures for preventing frost or minimising its effects are draining and piercing the forest with properly directed cleared lines, which create a continuous draught and thereby prevent cold air from collecting and stagnating in the hollows.

EXCESSIVE INSOLATION.—Excessive insolation injures, firstly, by drying up the soil, and next, by causing over-transpiration or even stopping all vital processes. The first danger is prevented by maintaining a sufficient number of parent or nurse trees until the component individuals of the young crop have so nearly met crowns everywhere and closed over the ground as to shade the soil effectively. The same measure will also prevent the second and third dangers, but in extreme cases it may be advisable not to remove all the nurses until the young crop has reached the sapling stage and has quite closed over the ground. In any case the degree and duration of the protection required here is much less than in the case of frost.

WINDS.—We have several times before this seen that extreme temperatures hurt most when air is in motion and that the injurious effect of hot or cold or dry winds is in proportion to their velocity. Hence when dangerous winds prevail, as they do in most parts of India, the only practical way to diminish their harmfulness to young forest growth covering a large area is to check their velocity. This may be done either by interposing a screen of trees, or by means of trees sprinkled all over the area as in stored coppice and in regeneration by seed under cover. In the former case, the screen has to bear the full brunt of the wind and must, therefore, be broad, tall and dense enough, and be composed, if possible, of trees that are in leaf all the year round or at least during the season when shelter is required. In regeneration under cover, a sufficiently wide belt of the original crop on the wind-struck edge should be preserved in the condition of an after-felling until the young crop behind is able to take care of itself; and if it is not full enough, the young growth under it should be supplemented and filled up with large transplants of some fast-growing hardy species. In the reboisement of large blanks the necessary screen should be raised in advance. In every case, the annual coupes should march against the wind and be as narrow as practicable. On hillsides a permanent fringe of forest, worked as conservatively as possible by jardinage, should be maintained along the highest edge of the forest. In a mixed crop, besides maintaining a protective screen, every effort should be made to obtain a sufficient and evenly distributed proportion of individuals of one or more hardy and quick growing species, which should be allowed to just keep ahead of their delicate neighbours.

WEEDS AND GRASS.—On rich, moist soils, young seedlings, particularly of species which are naturally slow in establishing themselves, are kept back for long years by weeds and especially grass. In some soils and climates, low shrubby species become even more dangerous than grass, since their root-system is stronger and their crowns more spreading and invasive. In all such cases, if the money and labour are available, the noxious vegetation should be got rid of to a sufficient extent to enable the seedlings to shoot ahead rapidly and close over the ground, thereby suppressing their enemies. It will generally be found most convenient and economical to clear out by the roots all this harmful growth along narrow parallel strips from 6 to 10 feet apart, wherever the seedlings have no fair chance of making headway.

INSECTS AND PARASITES.—As regards monkeys and destructive quadrupeds, they must either be destroyed or their numbers kept within bounds. Against insects we have only the following practicable remedies:—mixture of species, associating a sufficient number of broad-leaved trees with conifers, maintaining the leaf-canopy as close as economical and sylvicultural considerations will allow, keeping the soil and forest free of dead and dying trees and dead wood, encouraging every insectivorous creature that is not otherwise harmful, and securing by every means in our power a healthy and vigorous growth. In the case of fungus attacks very prompt measures are necessary. The trees attacked should be at once felled and burnt; and, if necessary, the soil in which they stood should be isolated by means of a deep circular trench. Flowering parasites, like *Loranthus*, figs, &c. are easily overcome in the regular fellings, which should remove trees infested by them. If these trees are too numerous to be all felled together, the worst cases should be got rid of first, and the expurgatory operations repeated as frequently as possible until the forest has been practically cleared of the pest.

ARTICLE 2.

DIRECTLY FOSTERING THE GROWTH OF THE CROP.

When the yonng crop is too dense or too open or is interspersed with blanks, the forester must step in and bring about the proper degree of density.

CROP TOO DENSE.—When standing too close together, the young plants not only press up against one another above ground and prevent the development of a sufficiently large assimilating surface in each individual, but also rob each other of nutriment in the

soil and hence remain starved. If this state of things is allowed to continue too long, especially in a poor soil, the young plants become permanently weakened, and no amount of subsequent thinning out will do them any good. If they are broad-leaved species, they will generally recover, but after heavy expenditure of time, money and labour, that might have been avoided by timely intervention on the part of the forester. To provide against overcrowding the young crop must be thinned out as soon as it is observed to form too close a thicket. The superfluous plants should be pulled up or dug out by the roots, if they can be utilised in filling up open places elsewhere; otherwise (and in this case, they will be selected from among the weakest stems) they should be cut off close to the ground with strong shears of the pattern represented in Fig. 116. A strong, sharp sickle or the forester's pruning knife (Fig. 121) will also answer, but will not be so expeditious. The operation should be repeated periodically as often as overcrowding occurs again by the expansion of the surviving individuals. If the crowded state has been allowed to continue some time and the stems have become excessively lanky, the necessary relief should be given very gradually and cautiously, otherwise the thin isolated stems would not only bend down, even under their own weight, but suffer from too sudden exposure to atmospheric influences and light, the portion above ground growing too fast for the roots. But oftenest the best thing to do is to clear parallel paths about three feet wide and a few feet apart through the young crop, and trust to a sufficient number of the plants along the edges recovering their vigour and growing up into strong saplings. In some cases of very heavy overcrowding another set of similar paths may be cleared at right angles to the first, thereby cutting up the young crop into a number of little squares. Where broad-leaved species have been cut back in clearing the paths, the shoots they send up may be stronger and grow up more vigorously than the seedlings in the preserved lines or squares, as the case may be, and thus help in forming the future forest. The clearing of parallel paths hence admits of two possibilities, one at least of which is, humanly speaking, sure to be realised. Besides this immense advantage which it offers, it also demands less labour, supervision and skill than the process of thinning out the crop everywhere. But it will have its place mainly in crops composed for the most part of shade-enduring individuals.

OPEN CROP.—Young saplings not sufficiently protected by trees above it, especially in poor soils or in one that has deteriorated at

the surface, often get arrested in their growth for years and sicken and remain smothered up in the midst of a dense thicket of masterful shrubs and undershrubs. The remedy to adopt is to fill up the young crop with some quick-growing and hardy species possessing a light cover, thereby enabling it to close over the ground rapidly and suppress the noxious vegetation. The introduced individuals will mostly be required only temporarily as nurses until the main elements of the crop have acquired vigour and grown sufficiently to form a more or less complete leaf-canopy by themselves. Sometimes indeed they may be valuable enough to be admitted permanently into the crop. The young nurses may of course, if uncommon foresight has been exercised, be raised contemporaneously with the crop requiring their aid; but it is usual to introduce them later, occasionally by sowing directly, more often by planting. In the latter case, the transplants are generally put out in lines rather far apart, sometimes in an irregular manner in the midst of the seedlings to be nursed. When sowing is resorted to, the nurse species should be sown either in lines alternating with the others, or mixed with them indiscriminately if the entire crop has been raised artificially, or in broken lines or plots in the midst of self sown-seedlings.

ARTICLE 3.

CLEANINGS.

Cleanings are operations by means of which all the hurtful and otherwise undesirable elements of a young crop are weeded out in a timely manner. It is seldom that a single operation suffices, for in no place must the leaf-canopy be ever opened out too much. Annual repetition would of course be the best thing in the interests of the crop, but such frequency is obviously out of the question and the only practical plan is to repeat the operation at fixed intervals, the length of which will depend on the rapidity of growth of the young plants.

The *hurtful* elements to be removed in each operation are—

(*a*) *Climbers.*—These should be pulled or dug up by the roots wherever they occur; they should not be allowed to shoot up again.

(*b*) *Invasive gregarious shrubs.*—These should be cleared away round a sufficient number of good seedlings, which they overtop or press up against. If the crop is still low they should be cut a foot or so below the level of these seedlings. The main point to aim

at is to enable the seedlings to meet crowns and close over and suppress the shrubby thicket as quickly as possible. But if frosts are to be feared, the clearing must be very cautious and gradual.

(*c*) *Stems of inferior dense-crowned species overtopping valuable seedlings.*—Such individuals, if the seedlings do not require any protection, should be cut off a little below the level of the latter. Otherwise their crowns should be circumscribed by judicious lopping.

(*d*) *Individuals of inferior, dense-crowned, faster-growing species standing on the same level as valuable seedlings and pressing up against them.*—Such stems should generally be cut back. If they shoot up again, they can only help to push up these latter until the next cleaning takes place.

(*d*) *Coppice-shoots when overtopping or pressing up against valuable seedlings.* Seedlings-shoots have obviously the same value as seedlings and should receive the same amount of respect. The obnoxious growth should be dealt with in the same manner as (*c*) and (*d*).

(*e*) *Stunted bushy growth interfering with the development of seedlings.*—Such growth should be treated like (*b*) But if there is no fear of frost and it belongs to valuable broad-leaved species that are absent or insufficiently represented at those points, some of it should be cut back to throw up a vigorous regrowth capable of shooting up in height. Stunted coniferous growth must of course be weeded out in any case.

The *undesirable* elements in a young crop are—

(*a*) *Coppice shoots where there is a sufficiency of seedlings of the required species.*—They should be got rid of, if their removal will improve the growth of their neighbours or if the value of the produce they can yield will at least cover the cost of their removal.

(*b*) *Individuals of inferior species, where the ground would be adequately covered without them and they are not required either as permanent elements of the crop or to afford shelter.*—These stems should, as a rule, be simply bent down to the ground, or broken or cut off a little below the height of the surrounding growth, so that they may help to maintain a complete covering over the soil and continue to support their neighbours, without hindering the expansion of their crowns. When their support is no longer required and they are large enough to sell well, they should of course be cut by the base.

(*c*) *Stunted bushy growth in the midst of abundant seedlings of*

the required species. By lightly pruning this stunted growth, the seedlings should be encouraged to shoot away rapidly ahead and, by expanding their crowns, to close over it. It may then be got rid of, if its sale at least covers the expense of removal.

(*d*) *Seedlings in which a thick brush of shoots has taken the place of the leader.*—If there are no better seedlings near by fit to form a permanent part of the crop, the brush should be cut off just above a strong bud.

(*e*) *Forked plants.*—Although forking never becomes permanent except in species possessing a distinct verticillate or opposite branching, still it always results, in a certain degree, in arrested growth. Hence forked stems should be weeded out; but when there are no better ones to take their place, they must of course be kept and the forking got rid of by cutting away or breaking off all the branches of the fork except the strongest. Saplings of broad-leaved, fast-growing species may, however, be cut back.

(*f*) *Plants possessing constitutional defects.*—These defects are twisted fibre, a squat habit, an umbrella-shaped crown, &c. As far as these defects can be recognised at so early an age and provided no large gap is caused or dangerous atmospheric influences admitted, the individuals presenting them should be weeded out.

General.—From the preceding remarks it will be observed that cleanings may be begun, in a certain limited sense, even in a crop that is not yet established, especially if it is composed wholly or very largely of mixed spontaneous growth. Usually, however, the first cleaning does not become necessary until after the crop is quite established and has entered the phase of rapid upward development.

In a pure crop the operation begins late, need not be repeated frequently, and is very simple, being chiefly restricted to the removal of sickly, inferior-grown or badly damaged individuals which overtop or press in laterally their healthy, well-shaped and sound neighbours.

In a mixed crop the work is very much harder, is costly, requires constant close attention and cannot be repeated too frequently. While the attention should be directed chiefly to the principal species, the interests of the auxiliary ones and the vast influence for good they can exercise on the growth of the crop as a whole must not be lost sight of. Even the accessory species must receive their due share of regard, instead of, as often happens, war to the knife being made against them. One great rule should, however, be invariably followed. In apportioning to each species

its part in the crop, all other considerations should yield to cultural requirements.

It is evident that, whether the crop be pure or mixed, all growth not rising much above the ground should be carefully preserved. It does no harm to the trees of the future, it protects the soil and the stems of those individuals, and prunes them and forces them up in height.

ARTICLE 4.

CARE OF ADVANCE GROWTH.

In treating of regeneration fellings for natural reproduction by seed, we have in various places explained how to utilise advance growth. The rôle played by such growth is, however of such vast importance, that we are justified in considering the subject in detail in this place.

Although it is very difficult to say beforehand how any given advance growth will turn out, nevertheless certain general indications are never wanting with the help of which, aided by local experience, a fairly correct judgment can always be arrived at. These are—

(*a*) *The species to which it belongs.*—We are here concerned almost exclusively with advance-growth of shade-enduring species, for seedlings of shade-avoiding trees will hardly begin to put in a permanent appearance until the crop presents the openness of a seed-felling. Many species, such as *Terminalia tomentosa*, *Hardwickia binata*, sal, &c., still retain, after many years of suppression, the faculty of shooting up again on being uncovered, especially if they are at the same time cut back.

(*b*) *Soil.*—The influence of soil is very great indeed. In rich and moist soil, *cæteris paribus*, the faculty of completely recovering after-continued suppression is retained much longer than in poor dry soil. This is more marked, the more superficial the root-system of the species in question is. A moist sub-soil is of great help to most species.

(*c*) *Age of the advance growth.*—The power of recovery is in direct proportion to the age of the advance growth, as long as the stunted stage has not yet been reached.

(*d*) *Condition of the leaf-canopy.*—This is the most important influencing factor of all. The quality of advance growth depends mainly on the proper density of the leaf-canopy overhead since its appearance. As a rule, the best advance growth is found along the edges of a forest, in gaps and under a canopy that is full of small open-

ings; in other words a moderately dense leaf-canopy is more favourable for the appearance and survival of advance growth than no leaf-canopy at all, which may be just as detrimental as a very dense one. As explained several times in Books I and II, it is of great moment whether, the density being one and the same, the leaf-canopy is formed by tall, lanky, small-crowned trees or by short-boled trees with deep crowns. Other important points to note are the intensity of lateral illumination and the time during which the advance growth has been under the influence of the cover in question.

(*e*) *Whether the advance growth in question consists of scattered seedlings or forms a group.*—As a rule, only a group of seedlings has any real value, but seedlings standing too close together are as little to be trusted as those that are too far apart. The size of the group has little influence on the quality of the seedlings.

(*f*) *Size, form and appearance of the buds, leaves and twigs, and thickness and aspect of the bark.*—This is self-evident (See page 135, para. 2)

NATURE AND EXTENT OF THE FOSTERING OPERATIONS.—The care of advance growth must begin from the moment it makes its appearance under an old crop. In order to help it, whatever has to be done afterwards to foster seedlings that come in as the result of the regular regeneration fellings, must be done here also—protection against outside injurious influences, thinning out, filling up, cleanings, the introduction in its midst of desirable species that are absent or insufficiently represented. But the most important thing of all to do is to take advantage of the thinnings and the regular regeneration fellings for making locally over and round it after-fellings according to the group method. In executing these special local fellings we must not of course neglect the interests of the parent crop as a whole, and large old trees should accordingly be removed in preference to younger ones.

GENERAL REMARKS.—Treated thus, advance growth will furnish most valuable material with which to form the future crop. It is a free gift from Nature, which we ought thankfully to make the most of. It helps regeneration operations to a wonderful extent, conduces to the desired mixture of species, and is equally useful whether we adopt natural or artificial regeneration. If neglected, the most promising advance growth will become stunted and bushy and will later on prove no slight impediment to natural regeneration by seed.

ARTICLE 5.

EXECUTION OF THE PRECEDING OPERATIONS.

The execution of the various operations described in this section requires constant and close attention, together with no slight amount of skill and local experience. Whenever possible, the Forest Guards themselves with their own hands should do the work, and by means of special rewards should be encouraged to take a pride in the well-being of the young crops in their beats. They should be made to understand that cultural work is at least as important a part of their duties as police and supervision of labour. However large their beats and little intensive the cultivation of their forests may be, a light axe and a sickle should form an essential part of their equipment, and they should not consider their daily rounds completed until they have cut several climbers or relieved several scores of promising young plants from actual or imminent suppression. In this manner, at the end of the year, hundreds of thousands of fine individuals of the coming generation will have owed their flourishing condition to their assiduity. Where all the work cannot be accomplished by the Forest Guards alone, they should be assisted, during the appropriate season, by men who have year after year been employed on such operations.

The following implements would be used with advantage :—

(i) *For cutting out by the roots*, picks, pick-forks (Fig. 40), axes, grubbing axes (Figs. 14 and 15) and hoe-axes (Figs. 16 and 17).

(ii) *For cutting close to the ground*, light axes and bill-hooks, and long-handled shears (Fig. 116) and the forester's pruning knife (Fig. 121), the last two where there is not enough room to wield an axe or bill-hook.

(iii) *For cutting up to the height of one's head*, light axes and bill-hooks, and pruning knives (Fig. 113).

(iv) *For pruning and lopping*, axes, pruning bills (Fig. 127) and special saws (Figs. 110 and 111).

The best time to undertake the various operations is generally the beginning of the season of vegetation, when both the vigour of the plants and the extent to which they can injure or be injured can be most easily recognised. Plants relieved of any hindrance to their growth at this time have before them the entire season for their unchecked development. But as it is not always possible or convenient to carry out such a vast amount of work within the few

days during which the plants are preparing to put forth their vigour, it may be allowed to go on all the year round, but more especially during the period from April to December in places where frosts occur.

SECTION II.
Subsequent fostering operations.

If the work described in the Section just completed has been well done, the crop will not only have become thoroughly established, but will also have been formed and moulded in a general manner on the lines on which it should grow up. All subsequent operations will have for their principal object the completion, in a special manner, of this work by giving to the stronger individuals, selected in accordance with both cultural and economical exigencies, the increasing growing-room they constantly require. This growing-room may be afforded *gradually* to all the more promising individuals of the crop in view of the prosperous vegetation and growth of the crop as a whole, or it may be given *in conspicuously liberal measure and by large instalments at a time* to a few of the best and most valuable trees the growth of which it is desired to force. We have thus two distinct kinds of THINNINGS, which we may qualify respectively as ORDINARY and PLENARY. We may also have to employ direct measures to correct defects in the shape and length of the boles of trees or to restrict their crowns in certain directions. These measures are PRUNING and LOPPING.

ARTICLE 1.
ORDINARY THINNINGS.

The object of this operation is to give to the individuals that form the principal part of a crop increasing expanding room both in the soil and in the atmosphere above in proportion to their increasing requirements, the grand result being the improved vegetation and enhanced growth of the individual trees as well as of the forest collectively.

Even if a forest were left to itself, the strongest individuals would in time prevail by gradually hemming in or suppressing and ultimately killing out all the rest. But this victory would be the result of a more or less prolonged struggle, during which they could not themselves escape suffering a certain amount of check, if nothing worse. It is to prevent this that thinnings are made. Thinnings are thus operations intended principally to favour the stronger individuals and to help them to get rid of their rivals be-

fore these can do them any harm. We have used the word "principally" advisedly, for it not unfrequently happens that the stronger individuals are neither the most promising nor the most valuable or desirable as regards species, and have, therefore, to be forced to yield the place to their weaker neighbours.

I. Advantages offered by thinnings.

Thinnings offer the following important advantages :—

(*a*) By opening out the leaf-canopy, they stimulate the growth of the individual trees as well as of the crop as a whole. It has been established by direct experiment that a certain minimum number of well-developed stems per unit of area, the number varying with the different conditions of growth, contains absolutely more wood than a larger number of stems standing closer together and, therefore, possessing less vigour of growth.

(*b*) They give us the most practical and effective means of regulating the growth of the forest and the formation of the boles of the trees according to our requirements. Their influence on the length, diameter and shape of the bole increases both the quantity and the usefulness of the timber in each tree.

(*c*) By strengthening the trees, they reduce the extent of damage caused by violent or hot or cold winds and by the weight of superincumbent snow.

(*d*) By removing all dead, dying, unhealthy and unsound trees and inducing a sound healthy growth, they diminish the severity of forest conflagrations, keep down the numbers of wood eating insects at the lowest limit possible, and restrict, if not entirely prevent, the attacks of destructive fungi.

(*e*) They augment very remarkably the sum total of production of a given area. Trees under suppression have practically ceased to increase in size, while their presence not only prevents their neighbours from spreading out as freely as they might, but may even weaken them through overcrowding. They are thus not merely superfluous, but positively harmful. Their removal would, therefore, have the twofold effect of immediately realising a not inconsiderable amount of more or less valuable produce, which would otherwise have been entirely lost, and of giving increased growing room to their vigorous neighbours, which would not be long in expanding themselves and completely filling up this addditional space. What is true of trees under suppression is also to a greater or less extent true of those which are beginning to be suppressed. Re-

membering these facts, let us consider what happens in any given forest-covered area. We know that at any given age it is not capable of producing more than a certain maximum quantity of wood; so that if at that age this maximum quantity is standing on the ground, no further increment is possible. But if some of the weaker individuals be now taken out, we know that the remainder will at once spread themselves out until the additional room made for them is once more filled up and the maximum production is again standing on the ground. Thus it becomes obvious that thinnings not only yield a large outturn of valuable produce, but also constantly maintain on the ground the maximum crop that the area in question is able to support at successive ages. We have as yet no rigorously accurate data regarding the total yield of thinnings; nevertheless German foresters believe themselves justified in asserting that it is in their country from 20 to 30 per cent of the total yield of the crop,* and that if the rotation be rightly chosen, it may aggregate as much as from one-fourth to one-third the yield of the regeneration fellings. Considered absolutely, it reaches its highest figure in conifer forests and on rich soils; but considered relatively to the total yield, it is proportionately higher on poor soils. The average annual yield of thinnings begins to diminish after a certain limit of age has been passed, which limit is of course different in different soils and in different classes of forest.

(*f*) They induce early fertility and increase the production of seed by enabling the trees to develop a strong crown and affording them more or less effective illumination. The result is the early appearance of advance growth, whereby the regeneration of the crop is singularly facilitated and the time required to obtain a new crop is very appreciably shortened.

(*g*) They enable the forest proprietor, when trees bearing valuable flowers and fruit, such *Terminalia Chebula* and *belerica*, *Bassia latifolia* and *butyracea*, &c., are present, to secure every year from an early age a not inconsiderable income from the sale of minor produce.

(*h*) By stimulating the growth of the trees which are to compose the exploitable crop, they shorten the rotation.

*. I have adopted Gayer's figures, but Heyer says that with a well-chosen rotation, the yield of thinnings will average from one-fourth to one-third the entire yield of the crop, and from one-third to one-half the yield of the exploitable crop. Bagneris in France goes further and states that for some species the outturn from thinings may sometimes equal that of the regeneration fellings; but it is to be remembered that in that conutry preparatory regeneration fellings are classed as thinnings. See Appendix A.

(*i*) In a mixed forest they place in the hands of the forester the most effective instrument he can have for securing any desired distribution of the various component species.

(*j*) By regulating the density of the leaf-canopy, they exert a potent influence on the degree of lignification of the timber in a forest.

(*k*) As a direct consequence of all the preceding advantages, the financial position of the proprietor is improved in a very remarkable manner, that is to say, his forest returns to him, as interest on the capital sum which it represents, a very much larger percentage than he would get if thinnings were altogether omitted.

(*l*) They enable an owner requiring a steady income from year to year, to make up deficiencies in the yield derived from other fellings. And if the owner in any year suddenly wanted an enhanced income, thinnings would afford him the means of taking out the additional outturn without hurting any portion of his forest.

II. Principles on which thinnings should be conducted.

The individuals composing any crop may, according to the vigour and fulness of their crowns, be grouped into the following five easily distinguishable classes :—

I. OVERTOPPING TREES, possessing exceptionally well-developed crowns.

II. DOMINANT TREES, possessing well-developed crowns. As a rule, these mainly form the leaf-canopy.

III. DOMINATED TREES, *i. e.* those about to be overtopped. These are generally trees that have recently been in Class II, but, owing to weaker growth, have been left behind in the race, Their crowns will be already found to be more or less contracted and in some of them incipient decline will be noticed.

IV. OVERTOPPED TREES.—Crowns very appreciably contracted either on every side, or one side only. In some species the boughs and other large branches will be found bearing an abnormal number of short twigs grouped together in thick bunches. These trees may either (*a*) have the clear sky above them but be closely hemmed in laterally, or (*b*) have only a part of their crown free, the rest being completely overshadowed. Not unfrequently many dead branches will be noticeable.

V. SUPPRESSED TREES.—Such individuals, if belonging to conspicuously shade-enduring species, may still have perfectly green crowns ; otherwise the crowns will be found to be quite dead or in a dying condition.

It is an essential rule in making thinnings that the soil shall not be uncovered to such an extent as to expose it to deteriorate and that the individual trees shall not be isolated to such an extent as to render them liable to get bent or broken. Hence the severity of a thinning will be different according to the different prevailing conditions of growth in each case. For all practical purposes, however, it is sufficient to distinguish three degrees of severity as follows :—

1. LIGHT THINNINGS, in which only suppressed trees are taken out. Such thinnings hardly help nature at all, but serve mainly to utilise stems that have have practically ceased to exercise any impeding action on the growth of the rest of the crop.

2. MODERATE THINNINGS, in which, besides suppressed individuals, category (*b*) of overtopped trees and a great many of category (*a*) are also removed. This will without doubt be the class of thinnings most widely used in India.

3. HEAVY THINNINGS, in which *all* suppressed and overtopped trees must disappear, and also perhaps a few of those that are about to be overtopped.

Which of these three kinds of thinnings to make in any given case will depend on—

(*a*) THE AGE OF THE CROP. It is evident that the younger a crop is, the greater will be the number of stems that can be safely taken out as well as require to be taken out. Schuberg's experiments in the Baden portion of the Black Forest gave the following figures for the average area occupied by each stem of the more important species at different ages :—

At 20 years	...	...	1 square metre
„ 40 „	...	...	4 „ „
„ 60 „	...	...	9 „ „
„ 80 „	...	...	11·7 „ „
„100 „	...	...	15·4 „ „

Arranging the above figures in a different manner, they show that if there are 1,000 trees at the age of 20 years, at the age of 40 years there will be only 250, at 60 years 111, at 80 years 85, and at 100 years only 65. These figures show clearly how much severer a thinning should be between the ages of 20 and 40 years than between 80 and 100 years, the severity being in inverse proportion to the age of the crop. Also see Appendix A.

(*b*) SPECIES. Trees require more room in proportion to their shade-avoiding nature, and hence a crop of a shade-avoiding spe-

cies must be thinned more severely than a crop of the same density composed of species more tolerant of shade. Schuberg's experiments in the Black Forest, in crops containing individuals from 40 to 80 years old, gave the average number per acre of stems of four several species as follows, the species being arranged in the order of their ability to endure shade:—

Spruce	...	860
Beech	...	690
Silver fir	...	610
Scots' pine	...	530

In other words, if the space occupied by the pine be represented by 100, the figures for silver fir, beech and spruce would be respectively 87, 69 and 63.

(*c*) *The soil.*—Owing to greater rapidity of growth and fuller development of both crown and roots, good soil will have on it fewer individuals than the same area of inferior soil, the difference however diminishing rapidly with age. This is tantamount to saying that the struggle for room both in the ground and in the leaf-canopy during the stage of longitudinal growth is severer and begins earlier, but is sooner over, in favourable than in unfavourable soil. In the case of some species the total extension of crown attained varies to such an enormous extent according to the soil in which the trees may be growing that individuals in good soil may possess a spread from three to four times as great again as those in poor soil; whereas in the case of species that affect poor soils the difference will all but disappear after an early age (only 30 years in the case of Scots' pine in Southern Germany) has been reached. The conclusion to be drawn from the above facts is that, the density of the leaf-canopy being one and the same, thinnings should be severer in good than in poor soils.

(*d*) *Elevation above the sea.*—Schuberg's experiments in the Black Forest show that the fertility of the soil and the density of the leaf-canopy being one and the same, the spread of the crown diminishes, that is to say, the number of stems increases, with increasing elevation above the sea until the cold becomes so excessive as to require the trees to be more or less isolated. He found that the numbers of stems at the several altitudes of 400, 800 and 1,200 metres were respectively as 100 to 126 to 244. The influence of elevation is greatest at a young age and with shade-enduring species and diminishes as the trees become older and less tolerant of shade.

(*e*) *Aspect.*—Schuberg's experiments show that in Southern Germany difference of aspect makes only a slight difference in the spread of individual trees, easterly and northerly slopes containing, area for area, only 5 per cent more stems than westerly and southerly expositions. In this country the extremes of heat and cold and of drought are so much greater than in Germany, that it is probable that the effect of aspect is also much more marked.

(*f*) *Gradient.*—The steeper the gradient is, the more light can trees forming a leaf-canopy receive laterally, and therefore the larger the number of trees that can stand on a given area.

(*g*) *Condition of the leaf-canopy,*—It is obvious that self-sown crops and those resulting from direct sowings require during the pole stage of growth heavier thinnings than crops composed of transplants, which necessarily differ very little from one another in either vigour or stature and all stand at regular intervals apart. Indeed we may in a general manner say that crops consisting of individuals of more or less one and the same height can hardly bear being thinned at all, since they contain next to no overtopped or suppressed trees and the removal of any one individual forms a more or less large gap, which generally takes some time to fill up. Where the overtopping, dominant and dominated trees are not sufficient of themselves to protect the soil, thinnings ought to be light or moderate according to the number and distribution of the overtopped trees. Where the crop is crowded, the thinnings should be heavy. We thus see that in one and the same crop the character of the thinnings may have to vary from point to point. When the suppressed and overtopped trees occupy a distinctly lower level than all the other trees, the selection of the stems to remove offers little or no difficulty. Such is also the case even when all the crowns form one compact mass together, provided the component species are shade-enduring, for then any slight mistakes that may be made would not be of much consequence, since they would correct themselves before any evil results could follow. In any case the experienced forester will never find any difficulty in distinguishing the vigorous and growing elements of a crop, which are after all the main thing to keep in sight in making a thinning.

(*h*) *Composition of the crop.*—From what has been said in respect of Advantages II, VII, VIII and X resulting from a mixture of species (pp. 108-113), it is evident that, *cœteris paribus,* thinnings should be heavier in mixed than in pure forest.

(*i*) *Exposure of locality to dangerous winds.*—In places exposed

to winds that are dangerous only on account of their violence, the crop should be formed of strong, well-rooted trees capable of offering the necessary resistance. To obtain such trees quickly, moderate thinnings should be made and these should be begun early and repeated at short intervals. In the case of very hot winds, which dry up the soil and blow away the covering of dead leaves, the undergrowth in the protective fringe maintained along the exposed edge of the forest can never be too thick, and hence thinnings should there be carefully avoided. To obtain further protection unthinned bands of forest, running at right angles to the wind, should be left at regular intervals throughout the entire area. Against very cold winds also the undergrowth should be preserved along the wind-struck edge of the forest.

(*j*) *The length and fulness of bole desired.*—Thinnings, up to the close of the stage of rapid elongation, will be light in proportion to the length of bole required and its approximation to a cylindrical shape.

Bearing all the foregoing considerations in mind, it may be laid down as a general rule that thinnings should each time remove from the crop as many stems as may be taken out consistently with keeping the soil sufficiently protected, producing the required length and shape of bole, and enabling the trees to afford each other all the mutual shelter and support they may be in need of. The previous condition of the crop being known, the severity of a thinning made in it may with accuracy be gauged by the number of stems taken out and left standing.

III. When to make the first thinning.

We have already said so much regarding the rapidly increasing growing room required by the trees composing a complete forest crop, that no further evidence is necessary to prove that, in order to keep up unchecked the continuous development of the trees, thinnings should be undertaken as soon as the keen stage of the struggle for existence has set in. This period is indicated by Nature herself by the crop beginning to present an overcrowded appearance. In favourable soils and localities the overtopping and dominant trees differentiate themselves from the rest of the crop at an early age; the moment this occurs, a thinning becomes both desirable and necessary. On poor soil, although the growth is sluggish and the stronger elements of the crop declare themselves after a protracted struggle, nevertheless the time for making the first thinning does not arrive the less early,

and the urgency of the operation is all the greater in order not only to help the struggling stems to secure an early victory, but even to save them from being unnecessarily weakened and perhaps permanently crippled. For the very same reason the urgency for a thinning is equally great in all crowded crops, and is doubly so, if they have sprung up from seed spontaneously or as the result of direct sowing, and if, in addition, the soil is poor. As regards crops consisting of stems of more or less the same height and vigour, it would be a fatal error to put off thinnings while waiting for the stems of the future to declare themselves; instead of a number of individuals, sufficient to form a complete crop, shooting away above the rest, in the majority of instances hardly any of the trees will ever show any marked superiority over their neighbours and the whole crop will be crippled in its growth. So that here again early thinnings must be the rule, the stems to be preserved being chosen not necessarily because they possess the highest vigour, but on account of the regularity of their distribution. Early thinnings are also required in the interests of shade-avoiding species, and in places exposed to dangerous winds, where the trees have to be specially encouraged to strengthen themselves as quickly as possible.

Indeed, there are in all only two cases in which thinnings may have to be delayed, *firstly*, when the component species clear their boles with difficulty or require to be forced up in height, and, *secondly*, when small wood possesses too little value for the produce of the thinnings to at least cover the cost of the operation. This second reason for delaying the first thinning is, however, often entirely illusory, as the accelerated growth of the fostered stems, and hence their increased money-value, may prove more than a set-off against any small excess of expenditure over the money return of the thinnings.

IV. How frequently thinnings should be repeated.

If the crop under treatment is required to produce only small wood, the rotation may be too short to admit of more than a single thinning, or there may be no time even for this one thinning. Otherwise more than one thinning must be made in order to allow the more promising individuals of the crop to continue their growth unchecked. Whenever, therefore, the crop begins to present again a crowded appearance, a fresh thinning must be made. The frequency of repetition will be in direct proportion to the rapi-

dity of growth of the overtopping and dominant trees. This will itself depend on the nature of the soil, locality and species, and for one and the same soil, locality and species, on the age of the crop. All crops grow most rapidly during the first half of their life, particularly during the pole stage. In India we have still to ascertain the periodicity suitable for our various species at different ages and under different conditions of soil and locality.

The interval between one thinning and the next will also, to a slight extent, depend on the severity of the former, for it is obvious that the more open a crop is, the longer *cæteris paribus* will it take to become crowded enough to require being thinned again. This remark must not, however, be construed into a justification for making heavy thinnings solely in order to lengthen their periodicity and thereby save expense; the severity of each thinning must be determined on entirely different grounds, which have already been considered in their proper place.

Crops of shade-avoiding species should be thinned lightly and frequently, so that they may always have sufficient light and yet never be opened out too much to the deteriment of the soil and the future reproduction.

V. Season for making thinnings.

In the interior of the Himalayas, where snow lies on the ground throughout the winter, the best time for felling the stems to be taken out is the early half of summer. Everywhere else the work may be safely carried on at any time between the close of one season of vegetation and the beginning of the next.

In crops composed of stems of some size, the number to be taken out is necessarily small and the care with which they should be selected is obviously proportionately great. Moreover the overtopped and suppressed trees are easily distinguished from the rest of the crop. Their selection and marking should, therefore, constitute a separate operation, which should obviously be effected while the trees are in full leaf. In young crops the selection and felling of the stems should always proceed *pari passu* with one another.

VI. Execution of the fellings.

The effect of thinnings on the formation, constitution and growth of a crop and on its yielding power is so great that their execution must be undertaken, or at least personally superintended, by the Forest Staff, and never left to the workmen. In old

crops, in which the trees to be felled are selected and marked in a previous separate operation, the forest officer himself or an experienced ranger should select the trees, working by successive sweeps, as in the case of preparatory regeneration fellings. In young crops, in which the stems to be taken out are both too numerous to be marked in a special operation and difficult to select unless each one is felled as it is selected so that the effect of its removal may become at once evident, they will be indicated to the woodcutters working constantly under the personal direction of the forest officer or a qualified assistant. In this way no mistake of a serious nature will be possible. In young crops of uniform age and appearance, however, the forest officer need himself thin only a few specimen patches here and there and leave an intelligent guard to continue the operation over the remainder of the area, as in such crops the work will consist mainly in taking out stems at regular intervals and can hence be reduced more or less to mere rule of thumb. Even the woodcutters should be men chosen for their skill, diligence and habits of strict obedience to orders.

The mistake has sometimes been committed of attempting to base thinnings on a fixed maximum girth above which no stem should be cut. No procedure could be more unscientific or reprehensible.

One cannot be too careful in carrying out thinnings in mixed crops. In such crops the taller and more vigorous trees will not always belong to the more valuable species, and must then be taken out for the benefit of individuals of these latter species which they may be injuring ; and besides this, many of the stems that require to be removed may have wide crowns occupying a large space in the leaf-canopy. Each thinning should therefore be effected in two separate operations. In the first operation the work should be confined to aiding or relieving struggling individuals of the better species, wherever it is certain that those of inferior ones are not required in the interests of the mixture. In the second operation, which may sometimes be usefully put off for a whole year, the attention of the forester will be directed to the prosperous vegetation of the crop as a whole.

When there are two stems standing so close to one another as to appear to have come up on one and the same stool, the weaker or less valuable of the two ought to be got rid of, if the crop is still young. But if the crop has attained a certain age,

then it is, as a rule, better to leave both stems standing, as the sudden isolation of either of them may result in the unhealthy growth or unsoundness of the other.

VII. Concluding remarks.

The foregoing remarks prove how important a part thinnings play in the treatment and life of a crop and how much attention, skill and judgment are required for their proper and timely execution. Those remarks also establish the following grand rule, which is to be followed in every case as closely as circumstances will allow :—BEGIN EARLY, THIN MODERATELY, REPEAT FREQUENTLY.

SECTION III.
Plenary thinnings.

A plenary thinning is a very severe thinning made after the close of the period of ordinary thinnings, and having for its object the complete isolation of the strongest and most promising and valuable trees of a crop, so that they may spread out unchecked and attain a given diameter in as short a time as possible. The thinning is usually severe enough to prevent the remaining trees from meeting crowns for the next 30-40 years. The complete interruption of the leaf-canopy necessarily implied in this system of felling presupposes the absence of any apprehensions regarding the continued protection of the soil, which is secured by means of a new growth forming a full undercrop and obtained either by natural or artificial means.

Plenary thinnings are too recent an invention in sylviculture to have yet been fully worked out to their legitimate consequences. Nevertheless several systems have already been under trial long enough to warrant the assertion that these thinnings are not only not opposed to Nature, but enable the forester to favour to the utmost the growth of his best trees and most valuable species, and even put into his hands a most effective means of increasing the proportion of these latter or of re-introducing them there whence uncontrolled fellings in the past have driven them out.

It will suffice, in a Manual written in the present condition of Indian sylviculture, to describe in a very summary and general manner the various systems adopted by European foresters in the interests of their own species. That some such system will ultimately be employed in our teak areas with immense benefit to that species admits of little doubt.

1. The young undercrop raised uniformly over the entire area.

SEEBACH'S METHOD.—This is the simplest of all the systems of plenary thinnings. As soon as a crop, that has been carefully strengthened by means of ordinary thinnings, has become fully fertile and a good seed year arrives, a plenary thinning is made of sufficient severity to allow the new crop to be completely established before the trees above can meet their crowns and reform the leaf-canopy. In Europe, where this system is in use in beech forests, the crop is opened out to such an extent as not to be able to close up again for from 30 to 40 years. If, in the meanwhile, it should be found that the thinning has not been sufficiently severe, a second operation is of course permissible in order to effect the necessary corrections. The rate of growth is found to be doubled by this method of plenary thinnings (increased from 1·44 per cent in an unthinned crop to 2·90 per cent in one that has been operated upon).

HOMBURG'S METHOD.—In this method, which is employed only in mixed forests, regeneration fellings on the uniform system are commenced early and it is these fellings which actually constitute the plenary thinnings, the after-fellings being made with a light hand and at long intervals. This method differs from the preceding in that in the latter the upper crop necessarily ends by forming a distinct leaf-canopy above the young one, whereas in this one the favoured trees either always stand apart from one another or in groups, their number and distribution being dependent entirely on the number of really promising timber-yielding stems present in the original crop. In the case of shade-avoiding species on good soil the number of stems may aggregate from 24 to 32, and even more, per acre; with shade-enduring broad-crowned species the number would obviously be less. The regeneration fellings or, in other words, the plenary thinnings are begun early, in order that the whole series may be carried out while the crop is still young and the trees in their full vigour of growth. Homburg's measurements, in forests of beech and oak with a slight admixture of ash, maple, elms and other species, give 1·4 per cent as the mean annual increment at the time of the first preparatory felling (age of crop about 70 years) and 4·8 per cent, or an increase of 3·4, for the following period of 17 years. These figures prove the necessity and advantage of beginning regeneration, if it is to be effected under cover, as early as possible.

2. The young undercrop raised in groups.

As in Homburg's method the regular regeneration fellings on the uniform system fulfil the object of plenary thinnings, so in this method the regular regeneration fellings in groups, begun early and carried through slowly, do the work of the same thinnings. The extent to which the period covered by the fellings should be prolonged beyond the time absolutely necessary for regeneration will depend on the suitability of the soil for the species to be fostered, being comparatively slight in dry poor soil.

In forests worked by jardinage also the regeneration fellings and plenary thinnings must be combined into one and the same operation, the area worked over at each point being somewhat larger than in the case of regeneration pure and simple.

3. The young crop raised artificially.

In this case the commencement of the plenary thinnings is not limited by the age at which the crop would become fully fertile, but may be undertaken as soon as the crop can be safely opened out sufficiently for sowing or planting under it. For this reason, instead of making only a single plenary thinning, as in the case of natural regeneration by seed, the desired ultimate isolation of the timber trees of the crop should be effected step by step, as the various component individuals considered together can bear further isolation and the undercrop requires brighter illumination. At first the plenary thinnings will be comparatively light, since during the period of their execution the lower crop must be still well sheltered, the soil carefully protected, and the individuals of the upper crop (still too young to have attained their full length of bole or to be free from the danger of becoming overgrown with epicorms) must be kept close together. For the same reasons that the first plenary thinnings should be lighter than the subsequent ones, their periodicity should be shorter. In oak forests in Germany treated under this system, this periodicity ranges from 5 to 10 years, while that of the later thinnings varies from 10 to 15 years. In choosing the trees that are to be preserved to attain exceptional dimensions no account should be taken of the manner of their distribution; they should be selected solely for their vigour and future value as timber trees.

This method of plenary thinnings is specially suited for shade-avoiding species.

4. *The young crop obtained with coppice.*

The conditions of this method are completely fulfilled in stored coppice worked on long rotations and with numerous standards. In the underwood there should be an abundance of some species capable of forming a close growth.

5. *Selection of the trees and execution of the thinnings.*

Considering the small number of trees to be left and that they must be the very best of the entire crop, their selection and exploitation call for even greater care and solicitude than the same work requires in ordinary thinnings. Obviously it is the trees to be preserved that must be marked, and as the felling, conversion and removal of produce are to be effected under the constant personal direction and supervision of the regular staff, it will suffice to mark the trees merely with a ring of white paint.

The selection should be effected in several operations, every tree likely to be fit for reservation being closely examined from several points of view, and carefully compared with its neighbour if two or more such trees stand together. The work of selection should not be considered complete until the marking officer has traversed the coupe in every direction and thoroughly assured himself that no mistake has been made. The following procedure may be recommended as giving the best guarantee against a faulty selection when only a single heavy plenary thinning is to be made according to Seebach's method :—First of all mark with a single splash of white-wash all stems belonging to species to be spared and otherwise presenting qualities that may render their reservation desirable. Then after felling all the rest, go over the ground again and put a second splash on those from among the remaining trees which are most deserving of preservation and are at the same time properly distributed. Now fell all the trees bearing only a single mark, and then go over the whole ground a third time, putting a complete ring of paint on those standing trees which are finally to be left and which it will not now be difficult to judge correctly.

It goes without saying that the felling, conversion and export operations should do as little damage as possible to the trees left standing. Often the crown will have to be lopped before a tree is felled, and the fall of the trees will in any case have to be carefully directed.

Plenary thinnings should be undertaken only when a sufficiently strong, highly trained, conscientious and active staff is available to carry them out to completion.

SECTION IV.

Pruning and lopping.

Trees may have to be pruned or lopped in order either (i) to produce a certain clean length of bole without knots and of as cylindrical a shape as possible, or (ii) to control and improve the growth and shape of the crown, or (iii) to restrict the crown in the interests of neighbouring individuals which they overhang or press up against. As regards the first of these three objects every one is aware that the higher up the crown begins, the more cylindrical will be the shape of the bole below ; and as regards the second, we know that when a portion of the crown of a tree has suffered damage from any extraneous cause whatsoever, the removal of the injured portion by means of a clean cut will not only arrest the progress of deterioration, but enable the crown to regain its former vigour.

On the other hand, pruning may be accompanied with serious consequences to the value of the timber in a tree. If a green living branch be cut off and the section remain exposed, even if sap does not ooze out and form a nidus for fungus spores, little radial rifts, as the wounded surface dries, will form, by way of which atmospheric moisture will enter and filter downwards into the bole, and with the moisture will come in fungus spores, so that decomposition and unsoundness will spread through the tree, and will continue to do so, even after the wound has been covered over with new rings of wood. The pruning off of dry branches or of dry jagged ends of branches will, if carefully effected, rarely do any harm, and indeed will, in most instances, prevent the spread of decomposition and unsoundness that most inevitably ensue if the entire dead branch or its jagged, water-absorbing end, as the case may be, is preserved. But, in any case, it is a matter worthy of remark that pruning is not attended with equally lamentable consequences for all species ; and hence only those species may be pruned which do not suffer any appreciable harm from it.

How to prune.

Dry branches should be cut off flush with the trunk, otherwise, as

the latter increases in diameter, an ever-increasing portion of the dead branch will be included in it, which, if it does cause decay to spread, can never form any organic connection with the surrounding living wood and must, therefore, determine a solution of continuity. Moreover, by taking the branch off close to the trunk, the section is soonest overgrown with new wood. For this last reason green branches also should be pruned off close to the axis that bears them. It is of no use, in the case of forest trees, to prune branches above 3 inches in diameter, for a wider section could never be covered over soon enough to prevent decomposition and decay from setting in.

The pruned section should have a smooth even surface, as a rough or spongy one will absorb or at least retain water. The best tools to use, according to circumstances, are pruning bills (Fig.127), pruning knives (Fig. 121), or special forms of saws possessing fine teeth, which do not leave a spongy section (Figs,110 and 111). The saws may be fixed at the end of a bamboo up to 12 feet long. In using bills, the branch, if thin, should be cut entirely from below upwards ; otherwise a deep preliminary cut should be made on the upper side and the work finished off from below. Pruning knives must of course be drawn from below upwards. When the branch to be removed is long and thick and weighted with leaves and twigs, it should first of all be shortened, otherwise the heavy leverage exercised by its weight would tend to split and tear off a portion of the bark and wood from the trunk. To prune off branches high above the ground light bamboo ladders should be used, or, in the place of ladders, poles having alternate notches cut on two opposite sides and shod at both ends in the manner represented in Fig. 112. The wearing of climbing irons should never be permitted.

To preserve the surface of section from atmospheric influences and from fungus spores, it should be carefully coated over with tar. The section of a dry branch will drink in this tar greedily and become completely inpregnated with it for a good fraction of an inch. The same will be true, but in a less degree, of green branches cut when the *sap is down.* Wounds made in a tree while it is in full vegetation, always *bleed*, and tar put over such wounds would not be able to adhere, much less get inside the grain of the wood. Moreover the exuding sap would obviously decompose and give the very best lodgment possible to fungus spores. Hence green branches should be pruned only outside the season of vegetation.

It is obvious that, in view of economy both of money, labour and supervision, pruning should not be undertaken as a separate operation, but combined with any other that may be going on at the time.

Special Remarks.

In pruning roadside, grove and garden trees, the value of which as timber trees is a purely accidental matter, a special device for shutting out all atmospheric influences and preventing the entry of fungus spores is to fix a thin tin-plate over the surface of section, after having coated it with tar. The plate should be of the same shape and nearly the same size as the wood-surface on the wound and be kept in place with small iron tacks driven through it along its edge. In a year or two the new growth of wood and bark spreading out from the edges of the wound will cover up the rim of the plate and completely shut out all air-communication with the outside.

CHAPTER IV.

Improvement Fellings.

So many of our forests have come down to us in a ruined condition that one of the most, if not *the* most important, problem that presents itself for solution to the Indian forester is how to treat those forests, so that while supplying from them the wants of the country to the utmost limit of which they are capable and paying into the Public Exchequer a large and steadily increasing surplus revenue, they may be brought as quickly as possible to their highest condition of productiveness. The solution of this problem, enormously difficult in itself, is rendered doubly so by four several circumstances which have operated against the progress of forest conservancy since its inception. The first one of these circumstances is the popularly accepted view that the Forest Department is principally and essentially a branch of the Revenue Department and that its work should therefore be gauged by the figures of its Annual Budget. The second circumstance is the extreme poverty of the people and the consequent miserably low standard of comfort prevailing among them. As long as three-fourths of the population are content to live, or cannot help living, in squalid huts open to all the inclemencies of the weather and containing no more furniture than a rudely made bed, and subsist on the cheapest and most easily prepared fare that is just barely sufficient to keep body and soul together, so long will it be impossible to work out, except at a heavy loss, the immense quantities of unsound, crooked, knotty stunted trees of valuable species as well as of large, well-grown timber of inferior kinds which mainly compose the present stock in those forests. The third circumstance is the necessity of supplying the vast wandering herds of cattle sufficient pasturage to keep them alive. The fourth and last circumstance, one which is happily now rapidly disappearing, is the opposition every where encountered by the Forest Department and based on the erroneous idea that it has interests necessarily antagonistic to the general interests of the country, and that when it only safe-guards the rights of succeeding generations in limiting the enjoyment of the present generation to the strict usufruct of the forests, it acts as *an oppressor of the people.*

The present ruined condition of our forests is due to the combined continued action, during successive centuries, of several causes, the principal of which are.—

(*a*) *Fires.*—The Vedic hymns afford evidence that at the time the Aryans were entering their new southern home India was covered with magnificent forests which were rarely burnt, and that one of the acts forbidden under religious sanction to themselves by the new settlers was to set fire to forests. But with increasing population, extension of cultivation and multiplication of herds, this salutary prohibition was gradually set at nought and ultimately forgotten, and in these days its revival by the criminal law is regarded as an immense hardship and undue interference with a necessary and time-honoured custom. How and to what extent fires injure forests has been fully described at pp. 433-4.

(*b*) *Reckless or uncontrolled utilisation.*—Before indiscriminate felling was stopped in our forests, it was a common thing to see a large tree felled in order to obtain by adzing only one or two small scantlings. If a single good log was required, several trees likely to furnish it were felled and only the best one of these utilised. To save trouble in felling and conversion, large trees were cut several feet above the ground from the point where it was thin enough for the purpose of the Vandal requiring it. When railway construction was begun in India, a clean sweep was made in all neighbouring forests of every tree that seemed large enough to yield a sleeper. In this way thousands of trees were felled which were never used up. This reckless felling brought matters to a crisis in the Central Provinces and led to the establishment of the Forest Department there. But in those forests, as in most others, the proverbial stable door was locked only after the steed had been stolen. In a word until the State undertook the protection of its forests, there was no thought for the morrow. Each one helped himself to what he wished, not only without stint, but in the most wasteful manner imaginable. In felling the trees nothing was done to save neighbouring individuals from being damaged, and the conversion and export operations were carried on with as little solicitude as the fellings. Nay, even since the organisation of the Department, it has been the practice in many of our forests to take out all the sound well-shaped marketable trees and leave principally the rubish standing.

(*c*) *Grazing and lopping for fodder.*—During the rains and cold weather, while the grass was green, the ground was trodden

by the feet of cattle into a hard pan, into which the small roots of seedlings could not penetrate ; and if some seedlings did succeed in sending down their roots deep enough to get a hold of the soil, they were either crushed under the hoofs of the animals or browsed down or broken, and thus kept back year after year with the result that they have now become permanently stunted, and mis-shapen or at least unhealthy and unsound. When the grass dried up, trees in leaf, especially those just bringing out their new foliage, were ruthlessly lopped, large boughs being cut off for a few miserable mouthfuls of leaves.

(*d*) *Wandering cultivation.*—As much as half, if not more, of the aggregate area of our forests has been under some sort of cultivation within the last two centuries. This cultivation was mostly of the kind described in the last para. on page 23. Where there was some semblance of settled tillage, the soil was still left full of stools and sucker-producing roots, which ultimately caused the fields to be abandoned and become covered with forest growth of a more or less inferior kind. If the soil was naturally a poor one, being never manured, it could bear crops for only a few years and had then to be given np to lie fallow for a long period of years. In this rude style of cultivation many large trees were allowed to stand in the middle of the fields, but were pollarded or heavily lopped to prevent them from damaging the crops. Such trees, models of beauty perhaps for the artist, but eye-sores to the forester, still cumber the ground over hundreds of thousands of acres of scrub and often also of a better class of forest. Even where the cultivation had been of a settled type, war, rapine, severe visitations of cholera, small pox, &c., or the death of a local celebrity led to entire villages being abandoned and becoming permanent wastes.

The result of all these and other causes of destruction or disorder, working continuously through generations and centuries, has been that most of our forests, besides being so extremely irregular and often insufficiently stocked, contain such large quanties of unsound or mis-shapen or unhealthy material, and, in many cases, also an inadequate proportion of valuable and even marketable species. In some, advance growth is abundant and renders their restoration and improvement easy ; in others it occurs only in patches few and far between or consists of sparsely scattered seedlings or clumps of

stool-shoots, the soil in the intervals being too hard and too much under the dominion of grass and masterful low shrubby growth to give any chance for the spontaneous appearance of reproduction within a reasonable time; while between these two extremes there is an infinitude of intermediate stages of regeneration.

If the market and the state of the finances admit of it, we may, according to the requirements of the case, either establish or complete the new generation by sowing or planting and clear away all the old stock, or we may adopt any of the methods of natural regeneration described in Book II. On the other hand, if such wholesale action is not possible, it will at any rate be our duty to remove, as quickly as the condition of the market and the accessibility of of the forest will allow, every portion of the unsound, unhealthy and otherwise inferior portion of the stock wherever it can at once be replaced by sound, healthy and valuable growth. In other and briefer words, we must carry out IMPROVEMENT FELLINGS.

It is thus evident that an improvement felling is not an elementary operation of a special kind not yet described in this Manual, but is essentially a composite one combining in itself the attributes and objects of every kind of felling already treated of. At points where utilisable advance growth exists, it will assume the character of an after-felling or of a jardinage cutting. Where the crop is too dense, it will become a preparatory felling or a thinning or a cleaning according to the age of the component individuals. In other places it may partake of the nature of a seed-felling. Where frost and other dangerous atmospheric influences are not to be feared and the soil cannot suffer from exposure, there a more or less large clearing may be made, if the whole of the standing stock is unsound or deteriorating and early regeneration is certain. In such places the younger individuals capable of throwing up good coppice shoots should be carefully cut back. Young damaged stems of valuable species should also be cut back, where the regrowth from them wonld improve the constitution of the crop. In frosty localities, where the forest is open, it is useless to attempt any cutting back, as the new shoots are bound to get frost-bitten in their turn and in the end prove no better than the original individuals. In such places the only resource left is to allow the standing stock to gradually make its way up and ultimately form sufficient cover and shelter for new reproduction from seed. Crowded advance growth may have to

be cut back or thinned out. In all this varied work, while clearing the forest of all unsound, unhealthy, deteriorating or harmful stuff, the main thing to aim at is to get the ground covered with sound, valuable and growing material as quickly as the circumstances in each case will allow. Moreover, in mixed forest, a proper distribution of the component species should not be lost sight of.

Appendix A.

The following extremely interesting figures giving the results of various degrees of ordinary thinnings in four several experiments are taken from Professor M. Kunze's remarkable articles in the *Tharander forstliches Jahrbuch* for 1884.

The quantities given are so many solid cubic meters per hectare.

Experiment I.

Experiment begun on self-sown crop of beech, average age 49 years, with a sprinkling of silver fir of mostly the same age; growth very vigorous; leaf-canopy everywhere complete. First thinning made at age of 49 years; three subsequent thinnings at intervals of 5 years.

All the figures were obtained by actual measurement, except the quantity of standing stock in area C at the commencement of the experiment, which quantity has been estimated.

A. Heavily thinned area.

		Timber.	Smallwood.	Total.
Standing stock at 49 years	...	110·11	87·96	198·07
Yield of Windfalls	...	0·31	0·14	0·45
„ Thinnings	...	33·70	53·81	87·51
Standing stock at 65 years	...	178·01	57·07	234·08
Total production up to 65 years	...	212·02	110·02	322·04
Increase since the age of 49 years	...	101·91	22·06	123·97

B. Moderately thinned area.

Standing stock at 49 years	...	104·02	86·97	190·99
Yield of Windfalls	...	0·07	0·04	0·11
„ Thinnings	...	11·34	39·02	50·36
Standing stock at 65 years	...	188·06	59·46	247·52
Total production up to 65 years	...	199·47	98·52	297·99
Increase since the age of 49 years	...	95·45	11·55	107·00

C. Unthinned area.

	Timber.	Smallwood.	Total.
Standing stock at 49 years ...	107·07	87·46	194·53
Windfalls	0·05	0·04	0·09
Deadwood	1·35	3·91	5·26
Standing stock at 65 years ...	199·66	82·34	282·00
Total production up to 65 years ...	201·06	86·29	287·35
Increase since the age of 49 years ...	93·99	—1·17	92·82

Experiment II.

Experiment begun on a furrow-sown crop of Scots' pine 19. years old; width of furrows 30 centimetres, interval between them 1 metre. First thinning made at age of 19 years, 4 subsequent ones at intervals of 5 years.

All the figures were obtained by actual measurement, except those for the quantity of stock at the commencement of the experiment, which figures are mere estimates.

A. Heavily thinned area.

Standing stock at 19 years ...	0·0	96·10	96·10
Yield of Windfalls ...	5·73	33·46	39·19
„ Thinnings ...	19·16	65·18	84·34
Standing stock at 40 years ...	194·51	76·81	271·32
Total production up to 40 years ...	219·40	175·45	394·85
Increase since the age of 19 years ...	219·40	79·35	298·75

B. Moderately thinned area.

Standing stock at 19 years ...	0·0	96·10	96·10
Yield of Windfalls ...	4·79	25·88	30·67
„ Thinnings ...	9·71	43·81	53·52
Standing stock at 40 years ...	174·56	79·01	253·57
Total production up to 40 years ...	189·06	148·70	337·76
Increase since the age of 19 years ...	189·06	52·60	241·66

C. Unthinned area.

	Timber.	Smallwood.	Total.
Standing stock at 19 years ...	0·0	96·10	96·10
Windfalls	5·63	57·77	63·40
Deadwood	3·03	5·62	8·65
Standing stock at 40 years ...	170·60	72·35	242·95
Total production up to 40 years ...	179·26	135·74	315·00
Increase since the age of 19 years ...	179·26	39·64	218·90

Experiment III.

Experiment made on a tuft plantation on square pattern of spruce 22 years old, leaf-canopy comple, growth in height and thickness vigorous. Five thinnings at intervals of 5 years.

A. Heavily thinned area.

Standing stock at 22 years ...	119·43	78·05	197·48
Yield of Windfalls ...	10·72	3·80	14·52
„ Thinnings ...	48·18	27·45	75·63
Standing stock at 42 years ...	304·90	91·17	396·07
Total production up to 42 years	363·80	122·42	486·22
Increase since age of 22 years ...	244·37	44·37	288·74

B. Moderately thinned area.

Standing stock at 22 years ...	108·76	74·84	183·60
Yield of Windfalls ...	11·22	4·09	15·31
„ Thinnings ...	26·06	25·62	51·68
Standing stock at 42 years ...	290·26	97·66	387·92
Total production up to age of 42 years	327·54	127·37	454·91
Increase since age of 22 years ...	218·78	52·53	271·31

C. Unthinned area.

	Timber.	Smallwood.	Total.
Standing stock at 22 years ...	114·10	76·44	190·54
Windfalls	9·05	4·20	13·25
Deadwood	7·23	16·52	23·75
Standing stock at 42 years ...	287·92	90·58	378·50
Total production up to age of 42 years	304·20	111·30	415·50
Increase since age of 22 years ...	190·10	34·86	224·96

Experiment IV.

Made on direct sowings of spruce effected in furrows 85 centimetres broad and 1 metre 70 centimetres apart; leaf-canopy complete, if we except three spots in area A where snowbreaks resulted in small interruptions. First thinning made at the age of 40 years, four subsequent thinnings at intervals of 5 years.

A. Heavily thinned area.

Standing stock at 40 years ...	212·75	139·49	352·25
Yield of Windfalls ...	42·78	11·95	54·73
„ Thinnings ...	107·76	67·29	175·05
Standing stock at 60 years ...	404·69	126·40	531·09
Total production up to age of 40 years	555·23	205·64	760·87
Increase since age of 40 years ...	342·48	66·15	408·63

B. Moderately thinned area.

Standing stock as 40 years ...	209·43	135·59	345·02
Yield of Windfalls ...	29·88	7·98	37·86
„ Thinnings ...	78·03	54·35	132·38
Standing stock at 60 years ...	367·52	91·42	458·94
Total production up to age of 60 years	475·43	153·75	629·18
Increase since age of 40 years ...	266·00	18·16	284·16

C. Unthinned area.

Standing stock at 40 years	...	Not known		
Windfalls	...	18·09	6·25	24·34
Deadwood	...	26·14	47·53	73·67
Standing stock at 60 years	...	410·81	121·85	532·66
Total production up to age of 60 years		455 04	175·63	630·67
Increase since age of 40 years.		Cannot be calculated.		

APPENDIX B.

TECHNICAL TERMS DEFINED.

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Fig. 1

Diagram illustrating relative growth of trees

Fig. 4

Fig. 3

Fig. 2

Pruning Hook

Fruit gathering implements

Fig. 5

Germination test bottle

Fig. 6

Hannemann's Germination Platter

Descubes del.

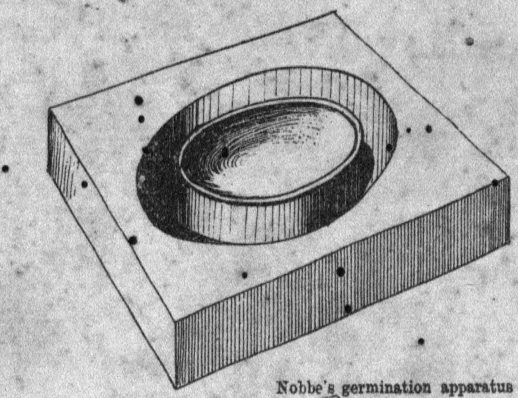


Fig. 7

Nobbe's germination apparatus

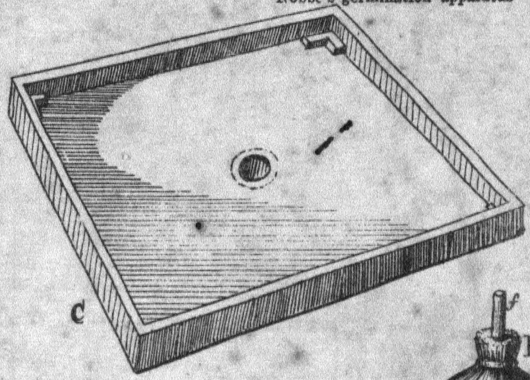
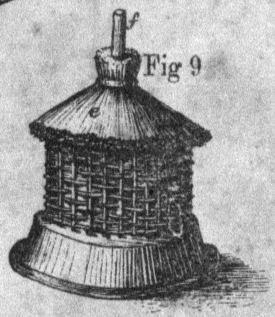
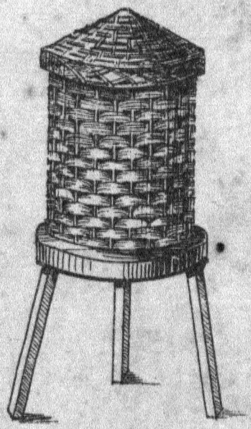


Fig 9



Shed for storing Seeds

Fig. 8



Basket for storing Seeds

Fig 9

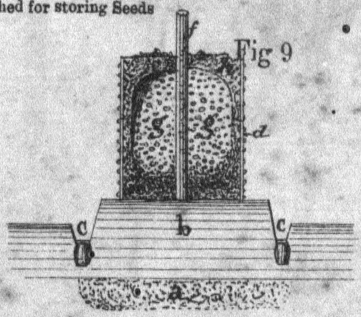


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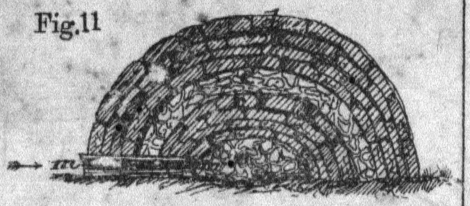
Fig 10

Sods for Turf

Fig.11



Surkhi-ash Kiln

Fig 12

Combined Fence & Mound

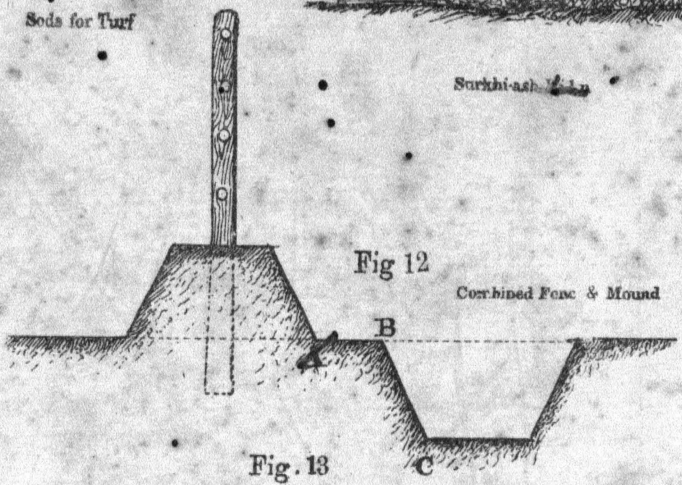
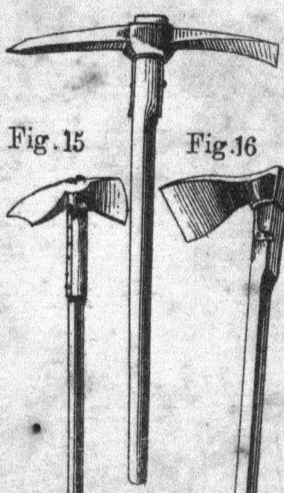


Fig. 13



Pick-Axe

Fig.14

Fig. 15

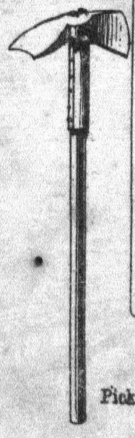


Fig.16

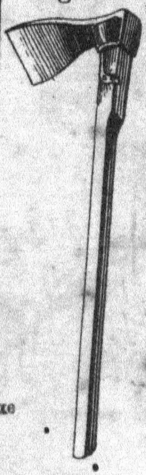


Fig. 17

Grubbing-Axes

Hoe-Axes

Descubes del.

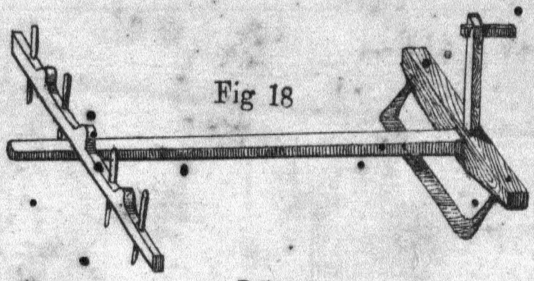


Fig 18

Bullock-Hoe

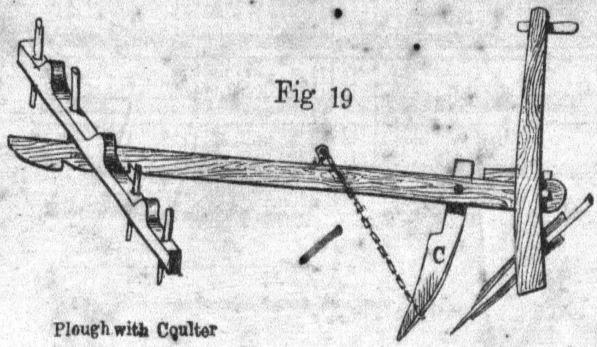


Fig 19

Plough with Coulter

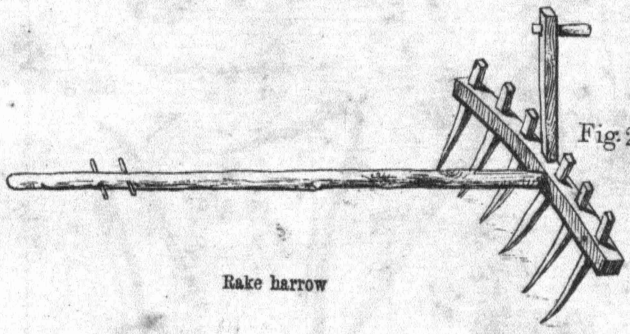


Fig. 20

Rake harrow

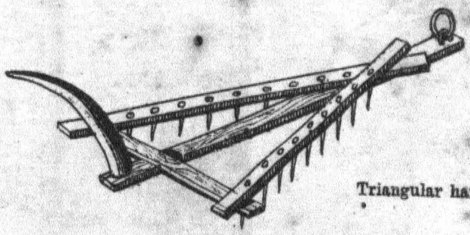


Fig. 21

Triangular harrow

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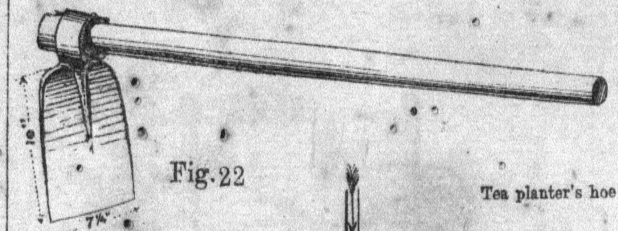

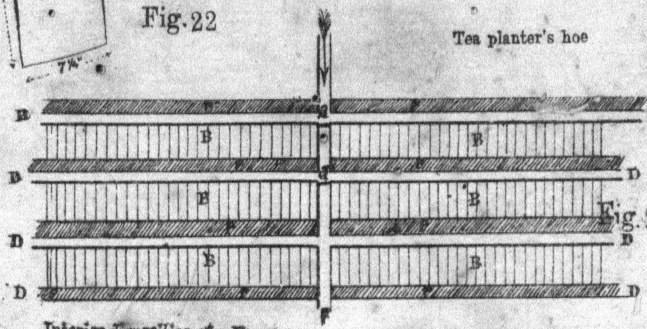

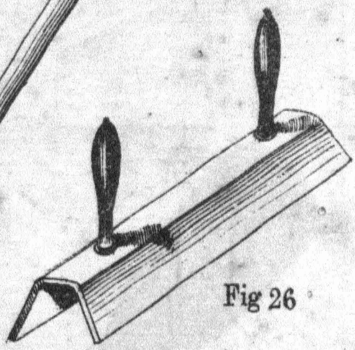

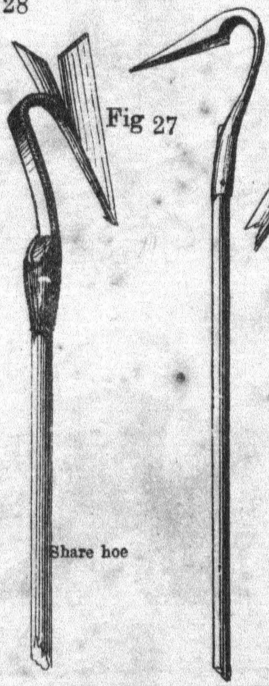

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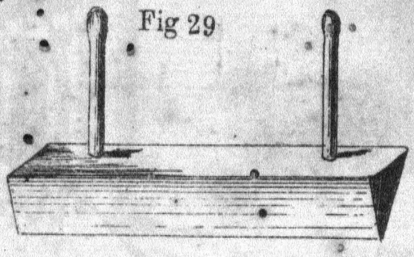


Fig 29

Sowing wedge

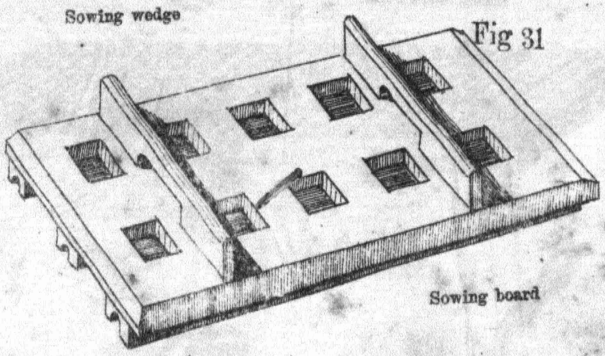


Fig 31

Sowing board

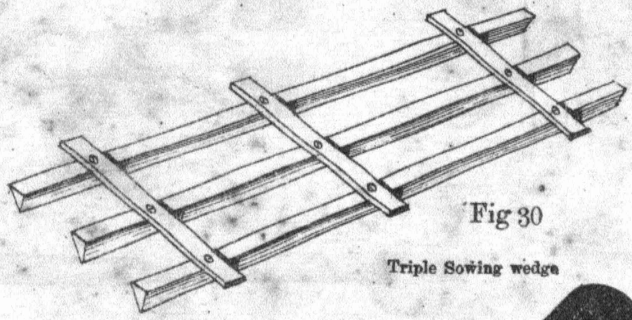


Fig 30

Triple Sowing wedge

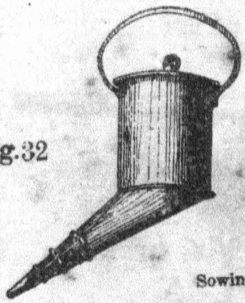


Fig. 32

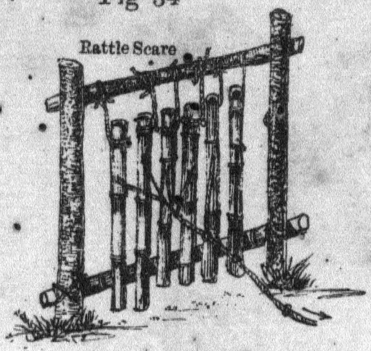
Sowing horn

Fig. 33

Sowing Bottle

Descubes del.

Fig 34



Rattle Scare

Fig 37

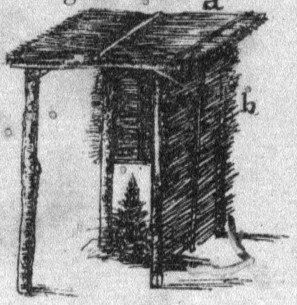
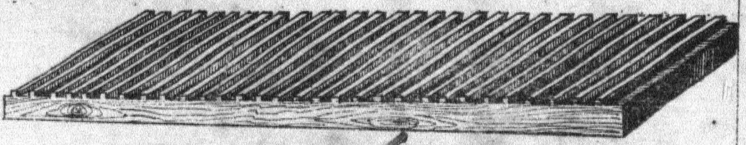
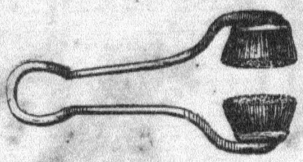


Fig. 35 Sun & Frost Shade



Coop for Seed bed

Fig. 36



Brush for insects

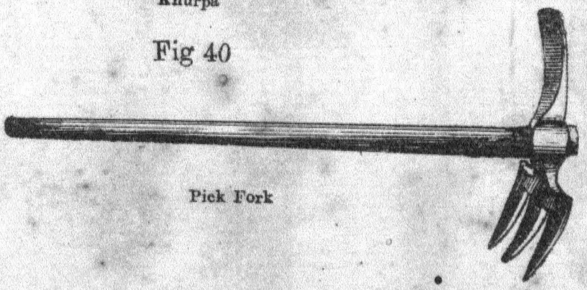
Fig. 38

Garden Trowel

Fig 39

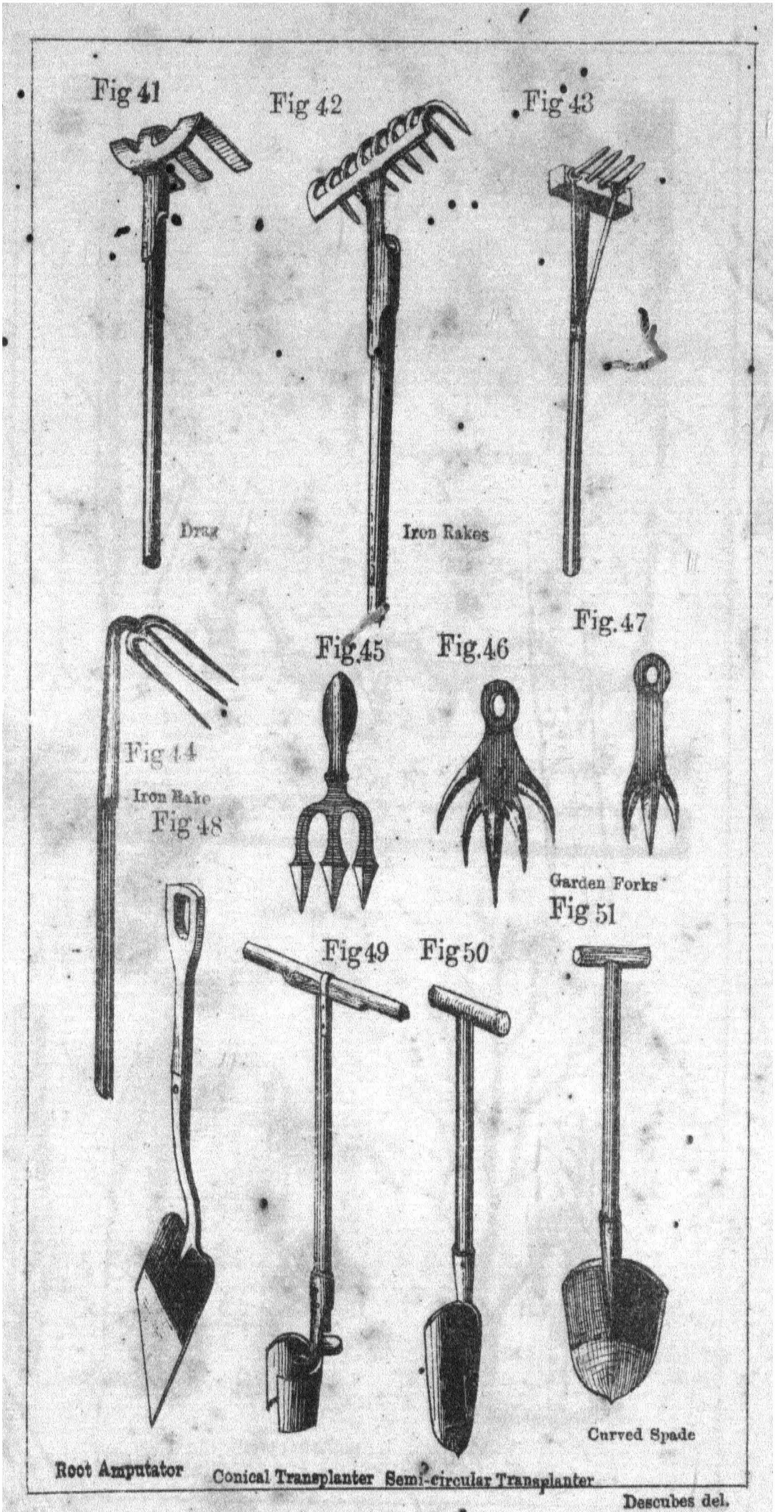
Khurpa

Fig 40



Pick Fork

Descubes del.



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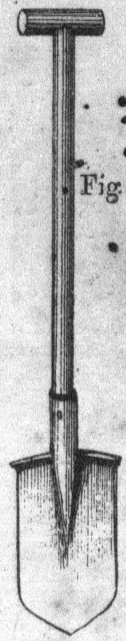
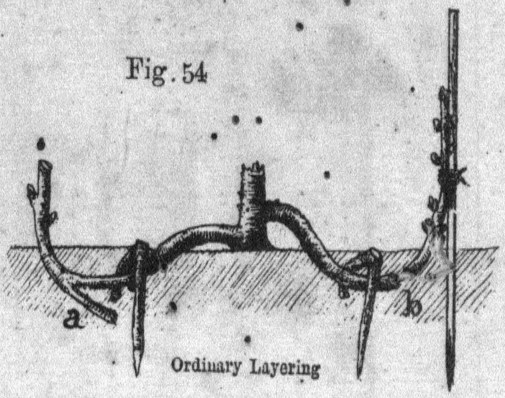


Fig. 52

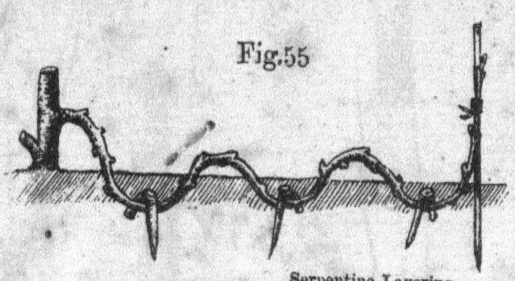
Flat Spade

Fig. 54



Ordinary Layering

Fig. 55

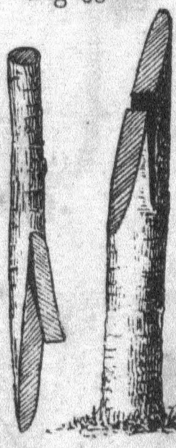


Serpentine Layering

Fig 53

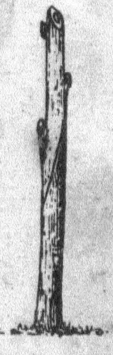
Planting Batten

Fig. 58



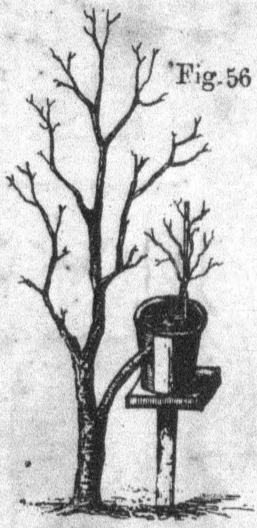
Tongue or whip Grafting

Fig. 57



Splice Grafting

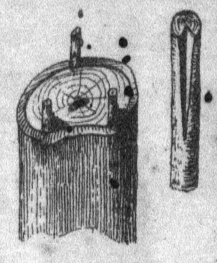
Fig. 56



Layering by circumposition

Descubes del.

Fig 59



Crown Grafting

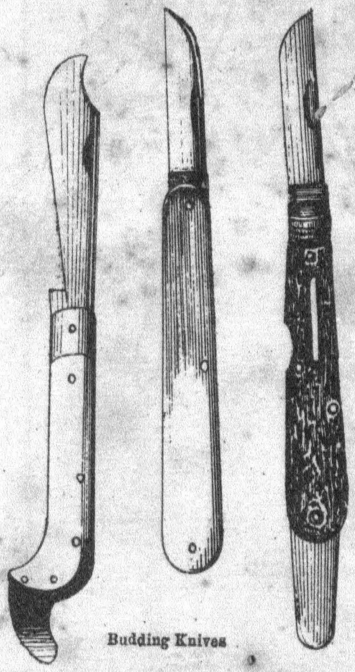
Fig 60

Cleft Grafting

Fig 61

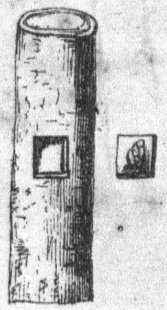
Saddle Grafting

Fig 62



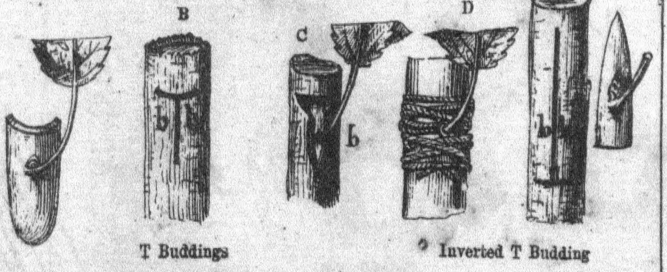
Budding Knives

Fig 64



Square shield-budding

Fig 63



T Buddings

Inverted T Budding

Descubes del.

Fig 65

A. Flute Budding

B. Ring Budding

Fig 66

Inarching

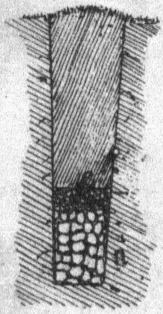
Fig 67

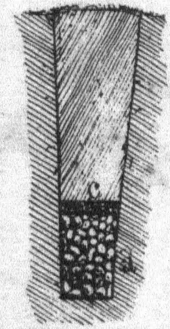
Fascine Drain

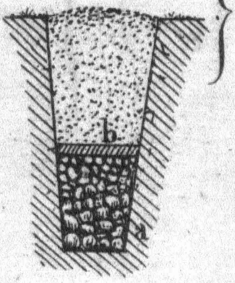
Fig. 69

Box Drain

Fig 68

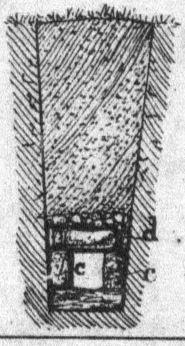


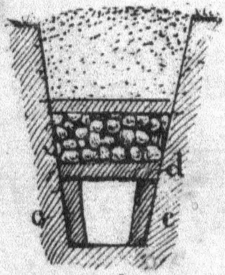


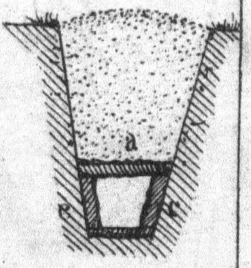


Rubble Drains

Fig 69







Box Drains

Descubes del.

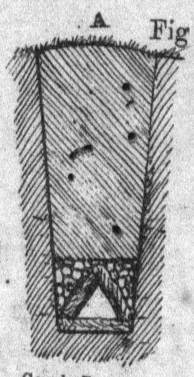


Fig 70

Couple Drains

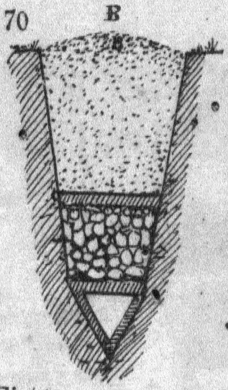
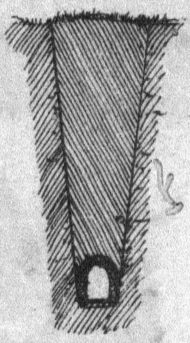


Fig 71



Tile Drain

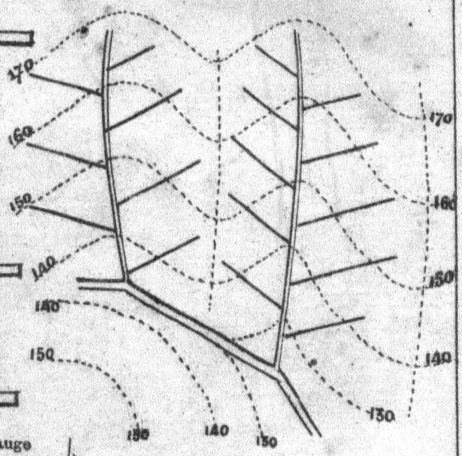
Fig.72

Bottoming Shovel

Fig.73

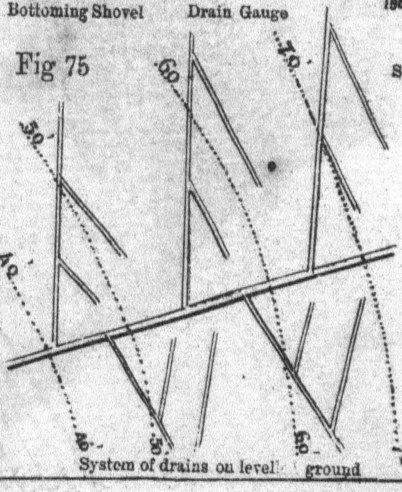
Drain Gauge

Fig 74



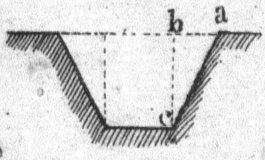
System of drains on pronounced Slope

Fig 75



System of drains on level ground

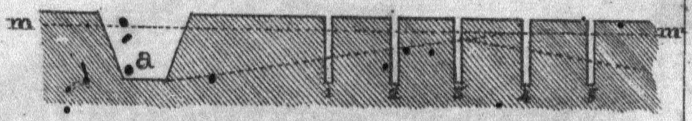
Fig.76



Section of Drain

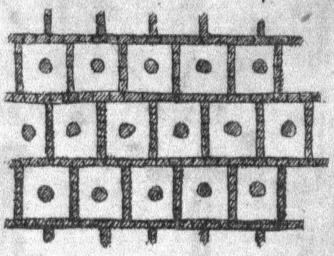
Descubes del.

Fig. 77



Interspacing of Drains

Fig. 78



Turfing Pattern

Fig. 80

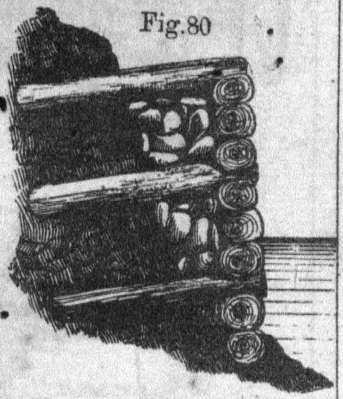


Fig. 79 Strong Revetment work

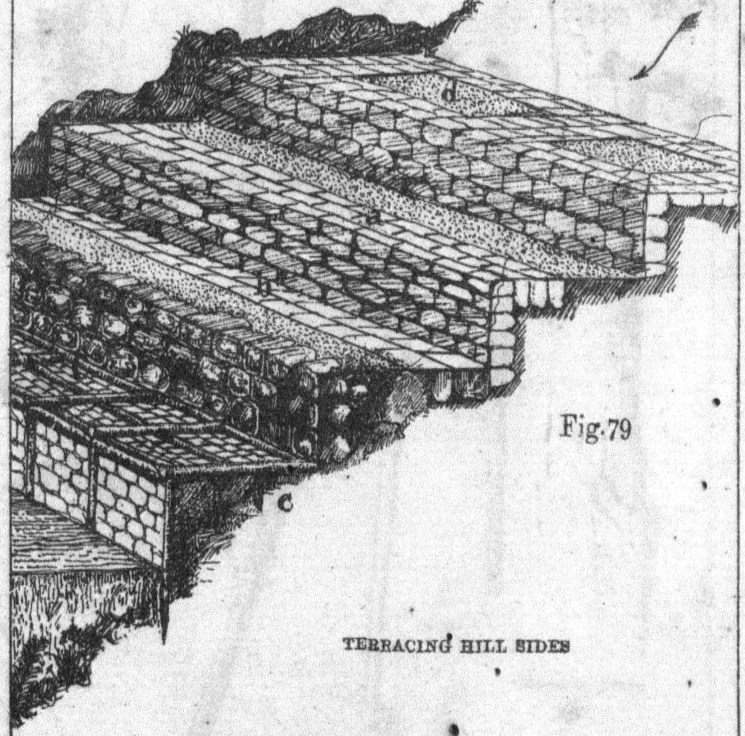
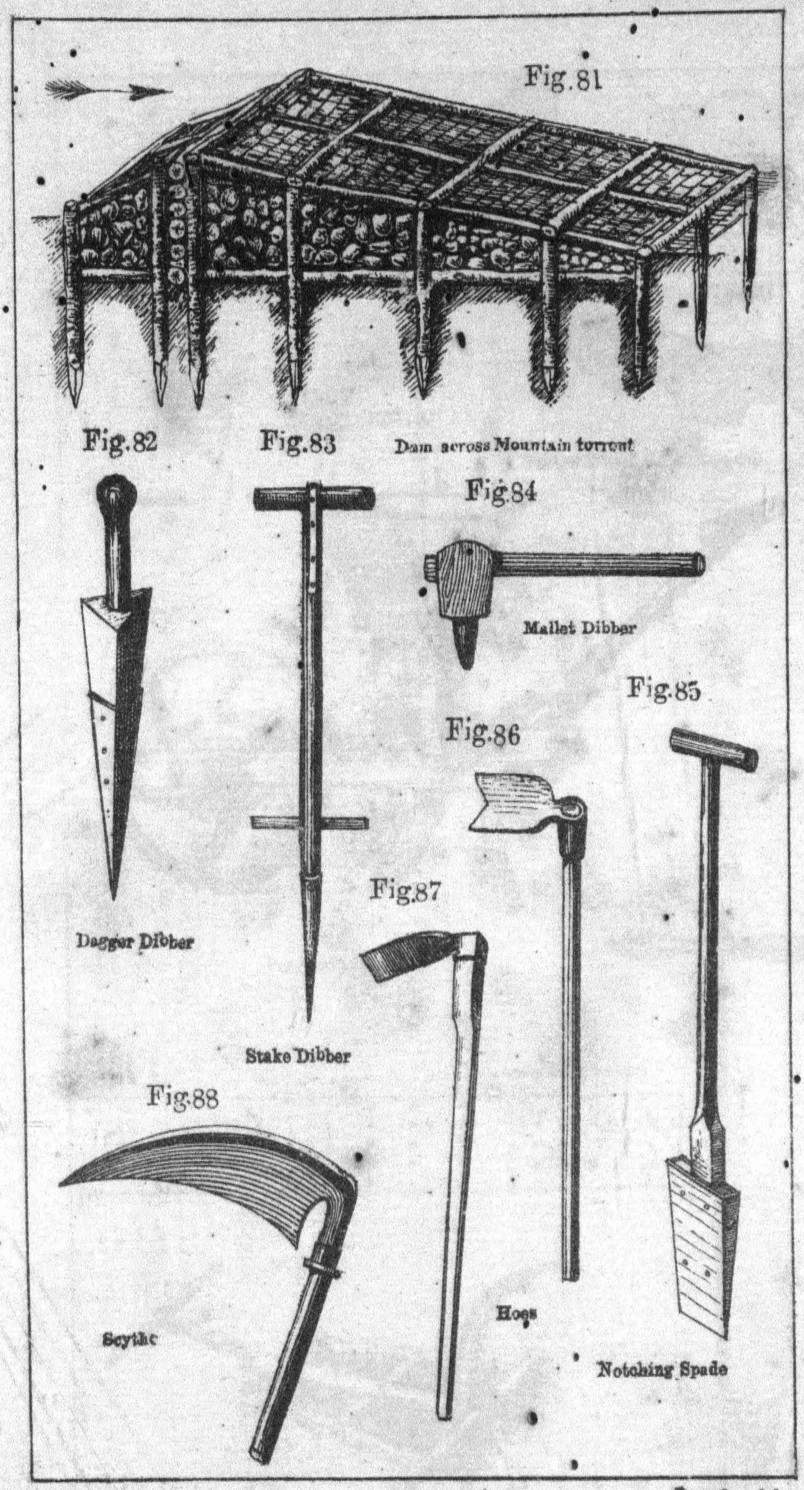


Fig. 79

TERRACING HILL SIDES

Descubes del.



Descubes del.

Sowing Tube

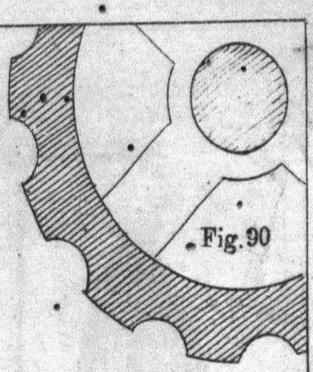
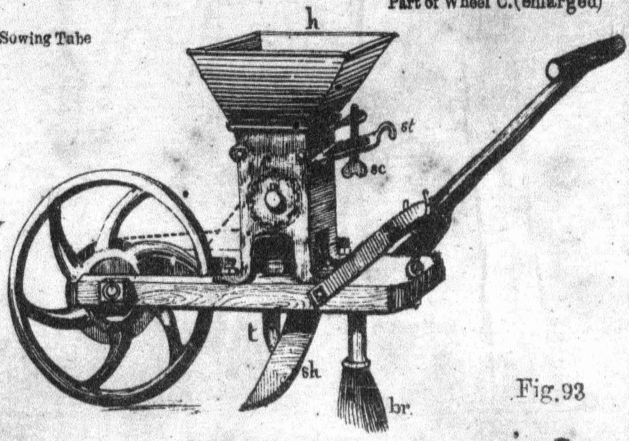


FIG. 90

Part of Wheel C. (enlarged)



Perambulator Drill

Fig. 93

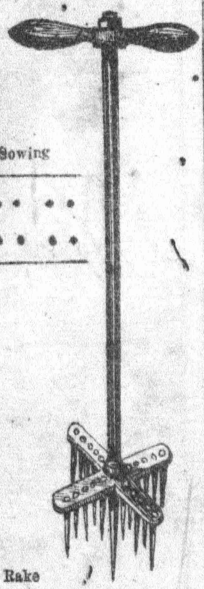


Fig 92

Pattern of Strip Sowing

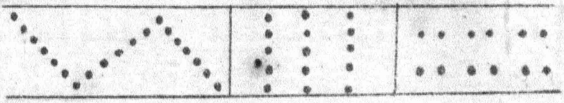
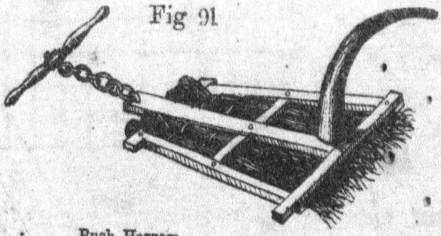


Fig 91



Bush Harrow

Torsion Rake

Descubes del.

Fig. 94

Fig. 95

Soil Augers

Fig. 96

Boring Tool

Fig. 97

Conical grass Shade

Fig 98

Rectangular

Fig 99

Square

Fig 100

Equilateral triangle

Fig 102

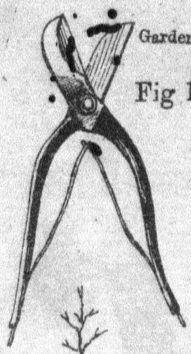
Check

Fig 101

Quincunx

PLANTING PATTERNS

Descubes del.



Garden Shears

Fig 103

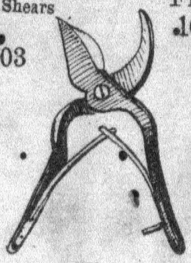
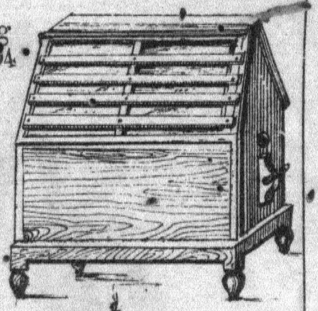


Fig 104



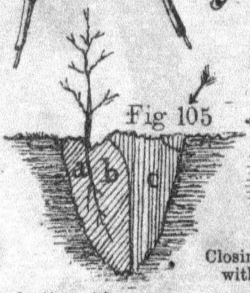


Fig 105

Pit planting with manure

Fig 106

Closing planting hole with dagger dibber

Wardian Case

Fig. 107

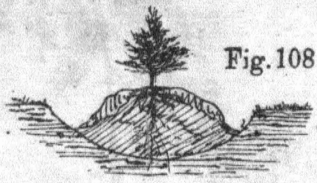


Fig. 108

Mound planting Patterns

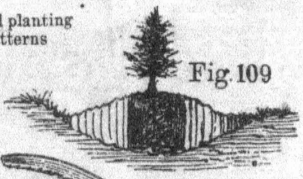


Fig. 109

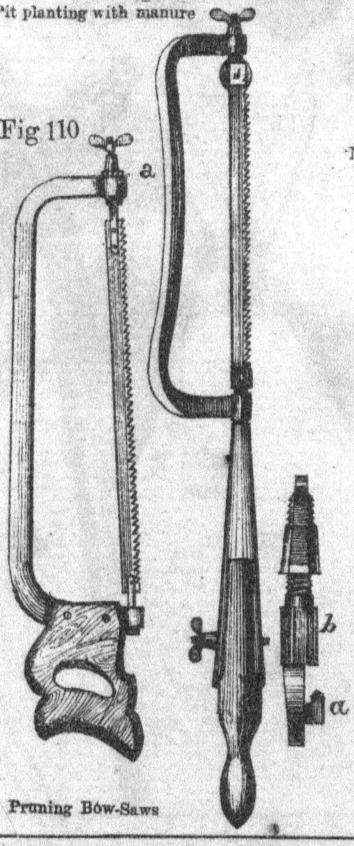


Fig 110

Pruning Bow-Saws

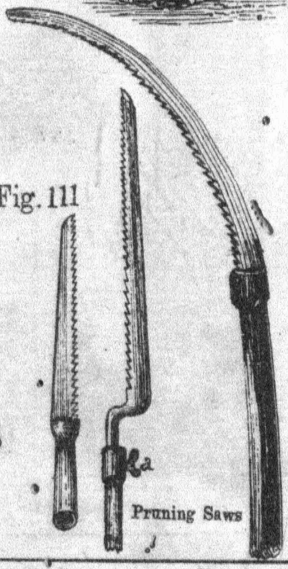


Fig. 111

Pruning Saws

Descubes del.

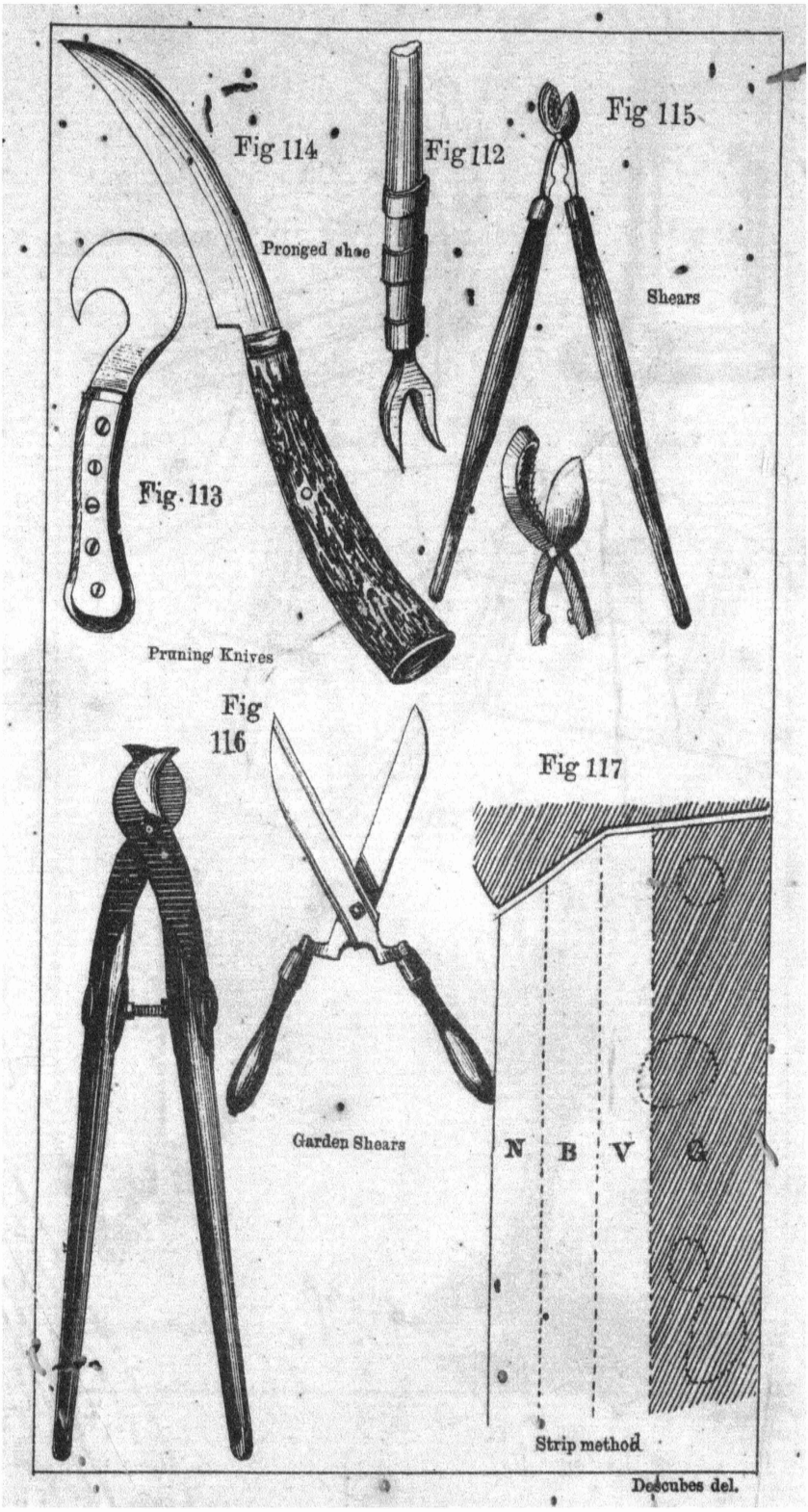
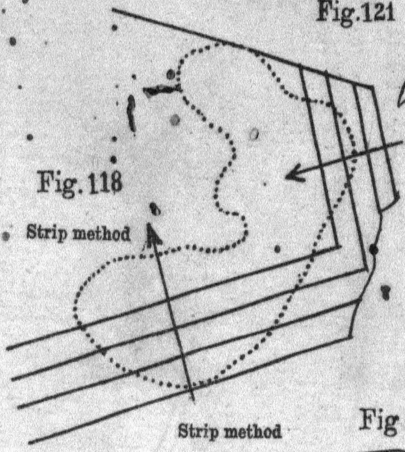


Fig 114
Pronged shoe
Fig 112
Fig 115
Shears
Fig. 113
Pruning Knives
Fig 116
Garden Shears
Fig 117
N
B
V
G
Strip method
Descubes del.



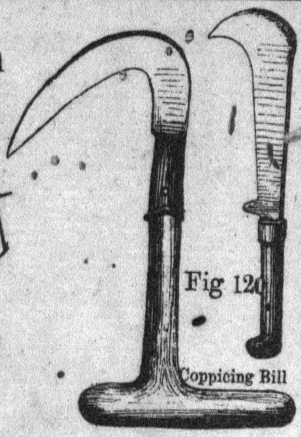


Fig 119 Pruning Knife

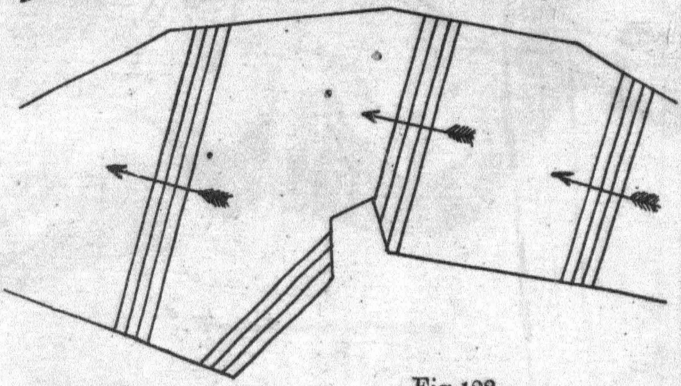
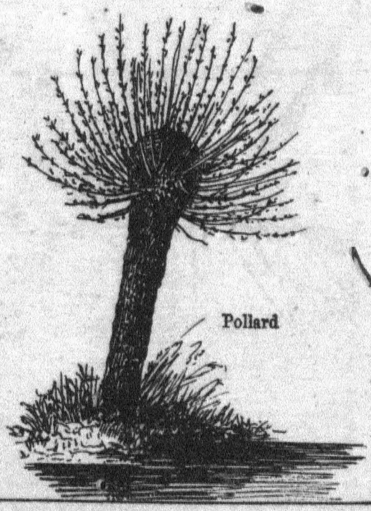


Fig.122

Coppicing Sapplings

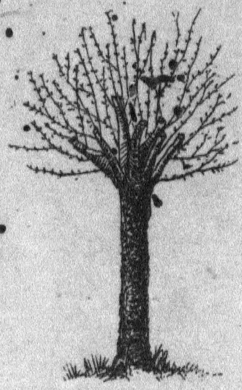
Fig.123



Pollard

Descubes del.

Fig 124



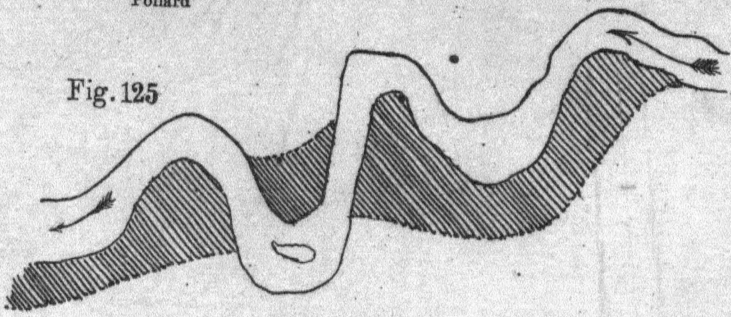
Pollard

Fig. 127

Pruning Bills

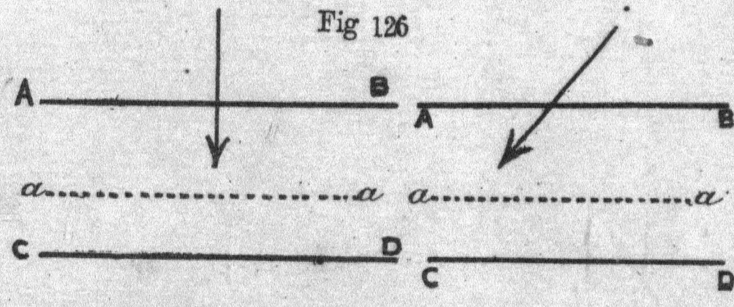
Fig 127

Fig. 125



Fire tracing along water courses

Fig 126



Fireing traces